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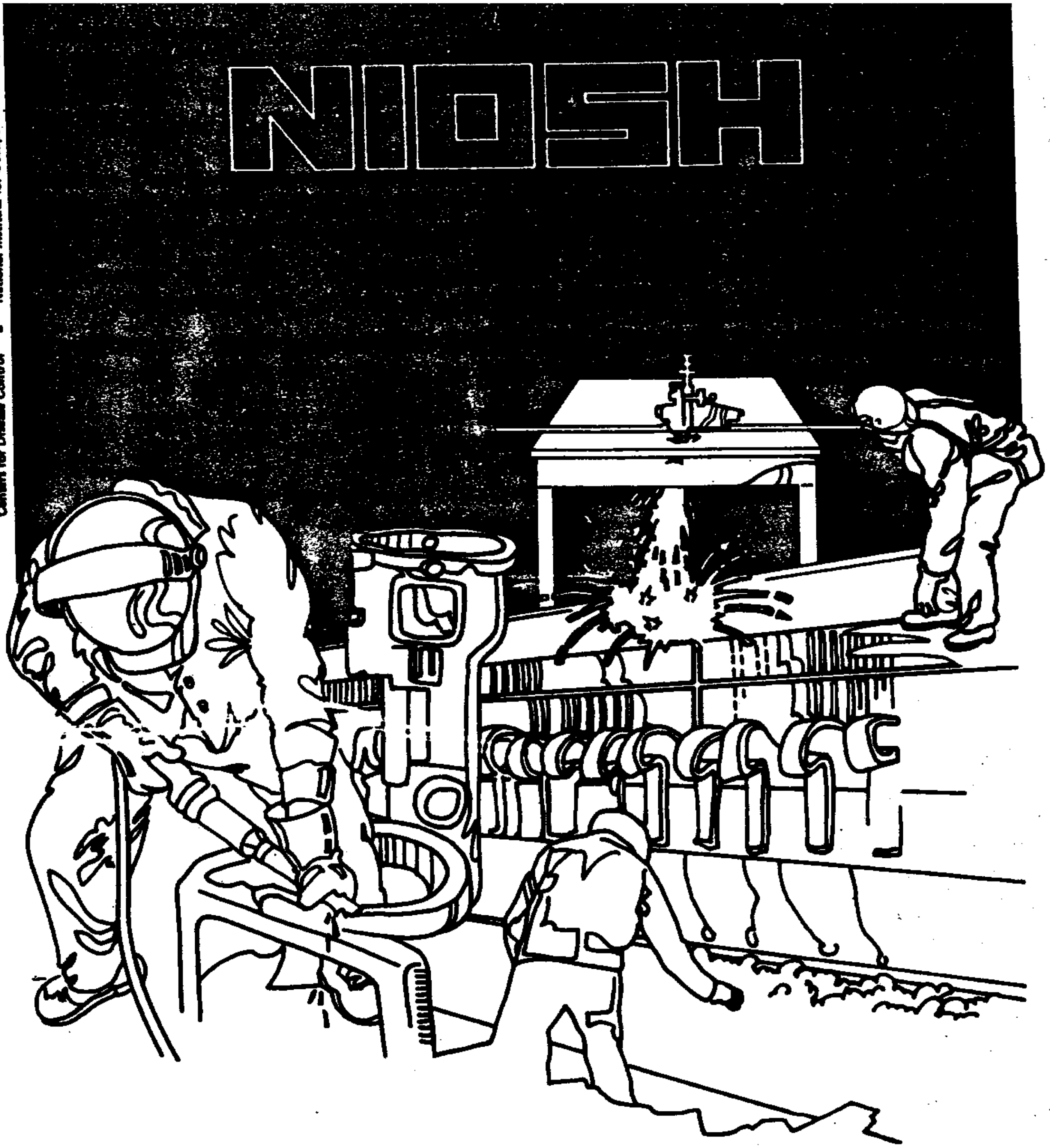

Health Hazard Evaluation Report

HETA 87-413-1921
MINISTRY OF HEALTH - ST. LUCIA
ST. LUCIA, WEST INDIES

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 87-413-1921
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MINISTRY OF HEALTH - ST. LUCIA
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NIOSH INVESTIGATOR:
Randy L. Tubbs, Ph.D.

I. SUMMARY

In September, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Ministry of Health, Housing, and Labour of St. Lucia, West Indies, to assist their country in the development of a hearing conservation program for newly emerging industries. Environmental health officers from the Ministry had participated in a training seminar on occupational health and safety in Trinidad from June 22 - July 2, 1987 which was presented by NIOSH and the Caribbean Epidemiology Centre (CAREC). During the seminar, the St. Lucians developed a proposal for a hearing conservation program for their country's industrial workers. They requested technical expertise and equipment support from NIOSH to initiate this proposal.

Noise surveys were conducted at several of the country's industries from November 1 - 14, 1987. The industries surveyed included paper converting and cardboard manufacturing, electrical power generator stations, cigarette manufacturing, beer brewing, clothing manufacturing, electronic components assembly, printing, plastic bag manufacturing, and soft drink bottling facilities. Although included in the evaluation protocol, no audiometric results could be obtained during the survey because of a shipping error by an air freight company which prevented NIOSH's sound attenuating chamber from arriving in the country during the period of the survey.

A total of 12 industries were each surveyed over a six to eight hour workshift to measure workers' noise exposures. From these 12 industries, 76 separate daily noise exposure measurements were obtained. The eight-hour time weighted average (TWA) values ranged from 73 - 106 decibels on the A-weighted network [dB(A)]. Six out of the 12 industries surveyed had at least one of their daily noise measurements in excess of the Occupational Safety and Health Administration's (OSHA) permissible exposure level of 90 dB(A) TWA.

A noise hazard was found to exist in several of the industries surveyed by NIOSH, indicating that many of the St. Lucian workers have the potential for occupationally induced hearing loss. Although audiometric testing was not conducted during this survey period, it is needed to gain additional information into the extent and severity ofthe workers' noise exposures. Recommendations to reduce the noise hazards for specific industries are provided in Section VII of this report.

KEYWORDS: SIC 2111 (Cigarettes), 2082 (Malt Beverages), 2086 (Bottled and Canned Soft Drinks and Carbonated Waters), 2342 (Brassieres, Girdles, and Allied Garments), 2381 (Dress and Work Gloves), 2647 (Sanitary Paper Products), 2653 (Corrugated and Solid Fiber Boxes), 2741 (Miscellaneous Publishing), 3079 (Miscellaneous Plastic Products), 3674 (Semiconductors and Related Devices), 4911 (Electric Services), noise, Caribbean.

II. INTRODUCTION

A basic course in occupational safety and health was held in Port of Spain, Trinidad from June 22 to July 2, 1987 for the staff of the Ministries of Health and Labour from four eastern Caribbean countries. The nine day seminar was sponsored by the Caribbean Epidemiology Centre (CAREC) and the National Institute for Occupational Safety and Health (NIOSH). During the course, the staff from St. Lucia developed a proposal for a hearing conservation program to reduce the amount of hearing loss resulting from occupational noise exposure being experienced by workers of their country. In order to initiate this proposal, the Ministry of Health of St. Lucia requested that technical expertise and equipment support from NIOSH be directed towards this project.

NIOSH investigators visited St. Lucia from November 1-14, 1987 to conduct initial site visits and noise surveys at several of the small industries located on the island. Original plans also called for the audiometric testing of workers at a select number of the surveyed industries. Because the country was totally lacking the facilities to conduct hearing tests, a portable attenuation chamber was shipped from the United States to St. Lucia to provide the needed quiet space to conduct valid tests. However, a series of errors by an air freight company prevented the chamber from arriving in St. Lucia in time to conduct the audiometric tests. Therefore, no hearing tests were conducted during this evaluation. The initial results of the noise survey were provided to the Ministry in an interim report in January, 1988.

III. BACKGROUND

St. Lucia is one of the windward islands located in the Lesser Antilles island chain of the Eastern Caribbean. It is situated between the islands of Martinique to the north and St. Vincent to the south. The island covers 238 square miles and has a population of 140,000 people. While the main industries of the country are agriculture (bananas and coconuts) and tourism, there are several manufacturing industries on the island. These range from small, single product firms to a very modern brewery. Most of the industrial facilities are located in the capital city of Castries in the northern portion of the island or in an industrial park near Vieux Fort on the southern tip of the island.

Twelve of these manufacturing industries were surveyed for employee noise exposures. With the one exception of a tobacco factory, all noise surveys were for 6-8 hours. The tobacco plant was only surveyed for 3 hours because of a reduced work shift on the day which this survey was scheduled. Only one day of noise sampling was conducted at each location because of a decision to maximize the number of different locations which could be tested during the two week survey period. A brief description follows for each of the facilities surveyed.

Winera Box Plant: This facility manufactures corrugated cardboard boxes from cardboard purchased from other companies. The factory has one corrugating machine, a glue mixing machine, a box folding machine, and a printing machine (ZLG Machine). Additionally, there is a cardboard compactor and scrap collector located in a corner of the facility where the scrap cardboard is compacted into bales. The facility also has storage areas for the rolls of cardboard material used in box making, storage for the finished product, offices, and a separate boiler room used to produce steam. There were approximately 35 - 40 production workers and other support personnel (e.g., maintenance workers and forklift operators) in the manufacturing area during the time of the survey. Eleven personal full shift noise samples were obtained at this facility.

LUCELEC - Vieux Fort: The electrical power for the southern portion of the island is generated at this diesel generator station. The building houses four diesel powered electrical generators, arranged with two generators on each side of the building with a central aisle. The operators can sit in a wood and glass enclosure built in the center of the generator floor. Approximately five operators and mechanics man this electrical generator station. Noise dosimeters were placed on four of the workers. However, one of the units failed to operate properly which left a total of three full shift noise samples obtained at this location.

Belles Fashions: This garment assembly facility is located in the coastal town of Dennery. It is comprised of two large buildings which house numerous sewing machines and work stations. Over 100 women are employed in the assembly of brassieres and panties which are sold in U.S. stores. The materials are manufactured in the U.S., shipped to Belles Fashions for assembly and packaging, and then returned to the U.S. for sale. The women sit at long rows of sewing machines situated fairly close together and perform the piecework assembly job to which they are assigned. Six personal full shift noise samples were collected on the day this facility was visited.

Tolyn Paper Company: This company produces rolls of toilet paper, dinner napkins, and facial tissue. The paper is shipped from Venezuela to Tolyn for packaging. The building houses machines for making toilet paper cardboard core rolls, for rolling paper onto these rolls, and for cutting the long rolls into the proper size of the finished product. Another machine folds paper into dinner napkins. Two other machines cut, fold, and package paper into facial tissue boxes for distribution. The remainder of the building is used for storage and for office space. Approximately 10-12 people were present during the shift surveyed. Four noise dosimeters were put on employees for the entire work shift.

Heineken Brewery: This modern brewery is influenced by its parent company located in Holland. The concept of a safe and healthy work place is evident in the management of this facility. Extremely clean working conditions and an enforced safety glasses program were immediately observed. The brewery is composed of a brew house, bottling hall, power plant, and storage facilities. During the survey period, construction was underway on additional buildings for the brewery. Approximately 50-75 workers were directly involved with the brewing, bottling, and storage of the beers at the plant. Additional people were employed to distribute the product and work in the large office facilities. A total of eight noise dosimeters were placed on employees for their work shift. One of the units did fail during the survey period.

NEHOC Gloves: This factory is housed in a large, single room building. It is engaged in the manufacture of white cotton work gloves. The process consists of stacks of white cotton cloth being placed in a hydraulic press with a cutter die in the shape of a hand. Two pieces of the cut cloth are sewn together by workers with small sewing machines. The gloves, which are sewn inside out, are given to workers who reverse the inside and outside of the glove with a metal rod and a hollow fingered hand form. The gloves are then moved to another table where they are bundled together and packaged for shipment. The work force at this facility is predominantly female with approximately 50-75 total employees. Three noise dosimeters were placed on workers at this facility during the work day.

Data Delay Devices: This large, one room building houses an electronic components assembly firm. The major products are printed circuit boards, integrated circuit chip assembly, and wire wound rheostat and potentiometers. The mostly female work force are involved with wire winding, soldering, and packing of finished materials. There is also a small quality control laboratory on the work floor for testing the integrity of the products. Approximately 50 workers were at the facility on the day of testing. Three personal noise dosimeters were located throughout the floor during the day. However, one of the units failed to operate.

LUCELEC - Union Station: This electrical power plant is similar to the station located in the southern part of the island. Union Station supplies electrical power to the capital city of Castries and the surrounding area in the northern portion of the country. This generator station has two more diesel generators than Vieux Fort and a more elaborate control system. There are also small mechanics' and electricians' workshops located at this facility. On the day surveyed, five of the diesel generators were on-line and operating. Approximately 25-30 operators, mechanics, electricians, housekeepers, and office personnel are employed at this station. Thirteen personal noise samples and one area sample were collected for an 8-hour work shift. One of the personal sample dosimeters failed during the day.

N.Y. Daher Tobacco Co.: This small company located in downtown Castries produced one brand of local cigarettes. The crowded, one roomed factory has a tobacco storage area, a tobacco cutting machine and drying machine, a machine for making filtered cigarettes, a cigarette packaging machine, and a bench where individual packs of cigarettes are bundled into brown paper cartons for retail sale. Approximately 10-12 workers are involved in the production of the cigarettes. On the day when the noise survey was planned, the company only had enough orders for the factory to work the morning half of the workday. Thus, seven personal noise dosimeters were placed on workers for only a three hour period.

Ramco Plastics Co.: This company produces a plastic film from raw materials and converts it into plastic bags for use in agriculture (banana plantations) and in commercial/residential uses (garbage bags). The back room of the facility houses the film making machines and a material grinding/reclaim machine. The front room contains the heat sealer/cutters which convert the continuous film into plastic bags. Both rooms are also used to store both raw materials and the finished products. Approximately 10-15 workers were in the production area at the time of the survey. Eight of these employees wore a personal noise dosimeter during their work shift.

DuBoulay's Bottling Co.: This bottling plant, located in downtown Castries, bottles Coca Cola products for distribution on the island. The production process starts with the washing of empty bottles which are conveyed into the bottle filling area. Here the product is put into the bottles, capped, and sent to the case packing area. Once the bottles are packed into cases, they are stored in warehouse facilities. Approximately 15 employees were needed for this process during the survey period. Five noise dosimeters were placed on employees throughout the facility to monitor the noise for the entire work shift.

Government's Printery: This two story building in Castries houses the Government's printing presses used to print official publications. The upstairs portion of the building is where the hand typesetters and monotype setters are located. The first floor has linotype, monotype, and cylinder printing presses. Approximately 12 employees run the printing operations. On the day of noise testing, six dosimeters were placed on employees located on both the upstairs and downstairs floors of the facility.

IV. EVALUATION DESIGN AND METHODS

The personal noise measurements were taken with Metrosonics Model 301-db Metrologgers with 1/8 inch remote microphones which were clipped to the shirt collars of the tested workers. These devices measure noise at a rate of 4 samples per second according to the OSHA 5 dB time/intensity trading relationship discussed in the next section. The dosimeter will measure the noise at this rate for a full one minute period and then store the resultant value into the storage mode of the unit. These noise samples were collected over as much of the eight hour work shift as possible, or as long as the worker was at his work station. The dosimeters were generally not taken off during the lunch period. Noise data collected with the Metrologgers were analyzed with a Metrosonics Model 653 Metroreader. The Metroreader also allowed for the storage of the data onto magnetic tape. Additional analysis of the dosimeter data was conducted with the Metrosonics dt-390 Metroreader/Data Collector and Metrosoft Computer Software.

A few area noise measurements were obtained with a GenRad Model 1982 Precision Sound Level Meter. This sound level meter has octave band measurement capabilities as well as the A, B, C, and "flat" weighting networks. All sound survey equipment was calibrated before and after samples were taken according to manufacturers' instructions with traceable calibration sources from the National Bureau of Standards.

It must be noted that each of the industries was surveyed for only a single day. Thus, it is impossible to ascertain whether or not these measured noise exposures are truly typical of the noise levels found in these factories. A more satisfactory scheme would be to measure the same workers over a three to five day period. However, in order to sample several of the industries present on St. Lucia, it was felt that single day measurements would be sufficient for a first approximation of the noise levels to which St. Lucian workers might be exposed.

V. EVALUATION CRITERIA

Exposure to high levels of noise may cause temporary or permanent hearing loss. The extent of damage depends primarily upon the intensity of the noise and the duration of the exposure. There is abundant epidemiological and laboratory evidence[1,2] that protracted noise exposure above 90 dB(A) causes hearing loss in a portion of the exposed population.

The Occupational Safety and Health Administration's (OSHA) existing standard for occupational exposure to noise (29 CFR 1910.95)[3] specifies a maximum permissible exposure level (PEL) of 90 dB(A)-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard[4], and the American Conference of Governmental Industrial Hygienists (ACGIH), in its Threshold Limit Values (TLVs)[5], propose an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average noise limits as a function of exposure duration are shown as follows:

Duration of Exposure (hrs/day)	Sound Level (dB(A)) NIOSH/ACGIH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115 *
1/8	115 *	-
		**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

When workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall also be implemented.

The evaluation criteria used in this survey were based on the United States' OSHA regulations as well as the recommendations of NIOSH and ACGIH. Because of the heavy influence of the United Kingdom on the business and commerce of St. Lucia, the rules and regulations of the U.K. for noise exposures should be thoroughly investigated by the Ministry of Health. If the International Organization for Standardization's (ISO) equal energy rules[6] are adopted, then a more stringent 3 dB time/intensity trading relationship would be used to calculate daily noise exposures. This would lead to TWAs of even higher proportions, indicating that the potential problem is even greater than first suspected.

VI. RESULTS AND DISCUSSION

The results of the personal noise dosimetry for all the surveyed facilities are summarized in Table 1. The table reports the number of dosimeter samples obtained at the facility, the average amount of time for the recordings, the 8-hour TWA calculated according to OSHA regulations, and the dB(A) range observed for the number of recorded samples. A total of 11 industries were surveyed over a six- to eight- hour workshift to measure workers' noise exposures. One additional factory was sampled for a three-hour shift because of a reduced workday schedule. From these 12 industries, 76 separate daily noise exposure measurements were obtained. The eight-hour TWA values obtained ranged from 73 - 106 dB(A). Six out of the 12 industries surveyed had at least one of the daily noise measurements in excess of the OSHA PEL of 90 dB(A) TWA. For three of the industries, the average TWA for the entire workplace would be in excess of U.S. regulations. When comparing the obtained dosimeter samples to the NIOSH REL, a total of 11 of the 12 industries were equal to or greater than the recommended level of 85 dB(A).

Each of the 76 dosimeter readouts are included as an appendix to this report (Appendix A). They will only be referred to in the discussion of the results. Each surveyed industry will be presented singularly in the remainder of this section.

Winera Box Plant:

The results from the personal noise monitoring are given in Table 2. The three primary machines found in the facility, the corrugated box, folding box, and ZLG machines, produce personal exposure levels in excess of 90 dB(A).

On the day of testing, the ZLG machine did not operate for the majority of the shift. Thus, the noise exposure for this operator was most likely the result of the noise produced by the corrugated box machine, located immediately across an aisle. The belief that this corrugated box machine is a major noise source in the plant is reinforced by the finding that the forklift operator also is exposed to a TWA of 90 dB(A). The operator of the forklift does not stay next to the corrugated box machine for the entire workshift, but rather moves throughout the facility. However, he was still exposed to a high noise level. The only operator surveyed for noise at Winera Box who is not in the area of the corrugated box machine is the boiler room operator. He is located in a different building and received a noise level of only 83 dB(A) on the day of testing.

The dosimeter readouts show fairly consistent noise levels between 90 - 100 dB(A) for workers in the main section of the plant, i.e., near the corrugated box machine. There are also three to four periods of noise levels which are 75 dB(A) or less. These periods are probably due to work breaks and lunch since, they occur at about the same time in each of the dosimeter readouts.

LUCELEC:

For the purpose of discussing the results, the findings from both electrical generating stations will be combined. The personal noise dosimeter results are presented in Table 3. These electrical power plants were the loudest industries surveyed. All 16 full shift samples were in excess of 90 dB(A). Seven of them were greater than 100 dB(A).

The primary noise sources are the diesel generators. Because they run constantly, the noise levels are quite consistent. Any variability in the workers' noise exposure is the result of the worker moving in and out of the generator floor and into the control room or workshop areas. This is clearly seen in several of the dosimeter readouts (Appendix A).

Area octave band sound levels were obtained at various locations in the Union Station generating facility. These results are given in Table 4. The two generators evaluated at Union Station emit a fairly wide band noise pattern. The octave bands from 125 Hz (cycles per second or Hertz) to 8 kHz (Kilohertz) were found to be similar in intensity levels. The noise levels fell off at the very high and very low octave bands. The C-weighted and A-weighted noise levels were nearly equal. The C-weighted network on a sound level meter generally measures sound as it occurs in the environment, allowing all sound frequencies to be summed with nearly equal relative weighting. The A-weighted network measures sound as the human ear perceives it, with the very high and very low frequencies having less relative importance than the middle frequencies.

The efficiency of the noise attenuation capabilities of the control room were also measured with the octave band sound level meter. The control room was very efficient in blocking out the higher frequency sounds produced by the generators, yielding as much as a 30 dB reduction. The control room's construction also reduced the low frequency sounds, but to a much lesser extent. Even with the attenuation afforded the workers who were able to go into the control room, it is still not enough of a reduction to be the sole noise control device. Noise levels in the room were measured at 85 dB(A).

Employees of LUCELEC were given the choice of two types of hearing protection devices (HPD) to wear on their job, the Bilsom® Propp-O-Plast ear plugs or the Bilsom® UF-2 ear muff. The efficiency of these HPDs was determined by calculating the noise reduction for each of these devices with NIOSH Method #1[7]. (For the purpose of information, the entire article explaining the three methods for determining HPD noise reduction is appended to this report.) The calculated dB(A)-reduction factor for this particular noise environment (Front #3 Generator) was found to be 24.1 and 24.9 dB for the Propp-O-Plast and UF-2, respectively. Given that the overall dB(A) value was measured at 108 dB(A), the effective dB(A) noise exposure to the workers is 83-84 dB(A) while wearing the HPD.

The attenuation values used in determining the dB(A)-reduction factor are supplied by the manufacture of the HPD and are based on optimal performance of the device (Table 5). This implies proper fit of the HPD on the wearer. This is more crucial for the ear plugs than for ear muffs. Because the HPDs chosen by the electric company are within 2 dB of the NIOSH REL, they may not be providing a sufficient margin of hearing protection for their employees. The high noise levels measured in this facility warrant the use of a more protective (higher noise reduction rating [NRR]) device.

Belles Fashions

The six dosimeters used at this facility were placed on workers in different areas of the two buildings to assess the overall noise exposures for the entire operation. Two of these dosimeters were placed on women who did similar jobs but had different age sewing machines. The noise levels measured during the day were generally in the low 80 dB(A) range, with only one TWA in excess of 85 dB(A) (Table 1). There was nothing which distinguished this latter job from any of the other surveyed jobs which would account for this small difference.

The comparison of the old machine and new machine yielded nearly identical TWA values, being within 0.5 dB(A) of each other. However, subjectively, the two machines did sound different with the older machine seeming louder. The lack of a difference in levels between the two may have been the result of the close quarters in which the women worked and that the interference of the other machines in the area overpowered any major differences between the two machines in question.

Tolyn Paper Company:

Three of the four personal noise samples were in excess of 85 dB(A) (Table 1) on the day of testing. The toilet paper rolling machine seems to be the major source of noise in the building. The operator of the rolling machine had the greatest TWA (88 dB[A]). The other two samples recorded at 85 dB(A) or greater were in the immediate vicinity of this machine. The lowest noise level recorded was for a woman folding napkins at a location more removed from the paper rolling machine than the other three. Anecdotally, the operator of the toilet paper rolling machine was observed tearing toilet paper from the roll, wadding it up, and putting it into each of his ears as homemade ear plugs. The company may find it worthwhile to buy this employee some type of HPD.

Heineken Brewery

The Heineken Brewery on St. Lucia is a modernized facility. Like its counterparts in other areas of the world, the production of the product also produces noise. The only area within the factory which was less than 85 dB(A) was the brew house. This is to be expected since this area is where the ingredients, once mixed, sit and brew into the final product. There is not much work in the area, so, consequentially, there is also little noise.

In the bottling hall and engine room, the work schedule is more constant and thus, the noise levels are greater. The average full shift noise exposure in the bottling hall was measured at 90 dB(A) (Table 6) and the engine room, or power house, was found to be 85 dB(A). Because this facility is already very modern in its operation, any engineering controls implemented in the operation would most likely be quite expensive.

The fork lift operator's noise exposure of 88 dB(A) may have been influenced by the large amount of outdoor construction going on at the facility during the survey. When the construction is completed, the noise exposure of this operator may go down. However, an additional personal noise sample would be needed from this worker to verify this speculation.

NEHOC Gloves:

The sewing machines used in this one-room facility were smaller than those used at Belles Fashions and also subjectively seemed to produce less noise. The hydraulic press used to push the glove dies through the cotton material also seemed to produce little noise. The full shift noise samples seem to verify this finding. All three dosimeter recordings were 85 dB(A) or less. It is worthy to note that the most obvious noise source in the factory was a radio playing music with the speaker placed on the wall at one end of the work room, the end with the sewing machines. Because the volume was increased so that the workers on the opposite side of the room could also hear the music, the people at the sewing machines were being exposed to rather loud music.

Data Delay Devices:

This one-room facility seemed rather quiet upon the survey team's first visit. It was chosen for inclusion in the study because of the number of such small, electronic manufacturers in the Caribbean. The two full shift samples obtained on the survey day confirmed the feeling that noise was not a problem. The TWA levels were measured at 73-74 dB(A).

N.Y. Daher Tobacco Company:

The four machines in this factory, a cigarette maker, a packer, a tobacco cutter, and tobacco dryer, all produced noise. Because of the smallness of the building, the four machines impacted all of the workers who were monitored for noise. This is borne out by the fact that the seven dosimeter samples only varied from 86-89 dB(A) TWA. These noise measurements included people who did not work on any of the four machines (i.e., the carton packers).

The survey period for this factory was shorter than the periods at the other surveyed facilities. This was because the orders for cigarettes on this day only warranted a morning work shift. Therefore, the dosimeters were on the employees for three hours. During the three hours, the machines were generally operating. Because the sampling period contained almost exclusive noise samples from operating machinery, the reported TWA values might be higher than if a full 8-hour workday had been sampled. A full work shift would also contain periods for lunch, breaks, and clean-up when the machines would not be operating. These quiet periods, when included in the calculations, would lower the measured noise exposure to the workers. This is one of the facilities which definitely needs to be surveyed again for workers' noise exposures.

Ramco Plastics:

The two rooms within this factory had very different noise levels. This is shown in the results given in Table 7. For the women operating the plastic bag cutters and the male material handler who supplied the women with plastic film, the levels were in the low 80 dB(A) range. However, the three workers in the other room with the plastic film extrusion process and the material regrinding process had noise exposures in the high 80 to low 90 dB(A) range. The regrinding machine was a particularly noisy operation.

The general appearance of this facility must be commented upon. The area of the material recycling had a very poor housekeeping policy. Discarded plastic film and old brown paper bags which used to contain raw materials were piled 10-12 feet high in the corner of the room. Finished plastic bags had been put into a storage area which was located in an upstairs loft over the bag cutting area. Evidence of falling stacks of bags was seen during the visit. There were also old, opened paint cans and chemical containers lying on the floor below the loft area. Finally, the only light into the room was from the outside. This appeared to be sufficient for the extruder room because of the large doors on both ends of the building. However, the few small windows on the walls of the other room did not allow nearly enough light into the work place. The overall feeling of the survey team was that this facility was a dismal place to work with several safety and fire hazards.

DuBoulay's Bottling Company:

This bottling plant is similar to bottling facilities in the U.S. The bottles are cleaned, inspected, filled, capped, and packed in cartons for distribution. The personnel in the actual bottling room were exposed to noise from the bottles hitting together on the conveyor belt as they moved through the process. The filling and bottle capping machine was also a source of noise. The levels measured by the dosimeters were 90 dB(A) and above for the workers sampled in this area.

The worker who placed the empty bottles onto the bottle washer was also exposed to noise levels of 85 dB(A) TWA from the bottles hitting each other and the noise from the washer. Finally, the case packer, who was located in a warehouse area of the company, was exposed to an impact noise source of 88 dB(A) from the hard glass bottles being dropped approximately 18 inches into the hard plastic soda cases.

Government Printery:

This small print shop has noise sources which are predominately the result of the operation of the printing presses. These presses are located on the bottom floor of a two story building. On the upstairs floor, where the the typesetters perform their job, the noise levels are low with TWA values less than 80 dB(A). The workers who operate the printing presses had TWA values between 78 and 83 dB(A). The one exception to this finding was for the worker who operated the monotype caster during the survey period. He had a full shift noise exposure of 89 dB(A).

Because the noise levels in the printery are dependent on how much the presses operate, additional noise measurements should be made when the operation is at capacity. Additionally, the use of lead in the set up of printing plates was noted during the noise survey. Because of the potential for neurological dysfunction resulting from exposure to lead, this printery should be surveyed for potential airborne lead exposure to the workers.

VII. CONCLUSIONS AND RECOMMENDATIONS

A noise hazard was found to exist in several of the industries surveyed by NIOSH. Of the 12 industries sampled for noise exposure levels, six had at least one 8-hour TWA measurement in excess of the U.S. OSHA's noise PEL of 90 dB(A). Eleven of the 12 surveyed industries had noise levels exceeding the NIOSH REL of 85 dB(A).

Based upon the data obtained in this evaluation, we recommend that:

1. Personnel from the Ministry of Health should return to the 12 factories where this survey was conducted with copies of the report to be distributed to both management and labor representatives of the respective companies. The Ministry of Health officers should explain in detail what the results from a particular company mean for that company and its employees. It is only with this type of feedback that any program of hearing conservation will have a chance to be implemented.

2. The Ministry of Health should pursue the need for audiometric testing of the workers of St. Lucia. Selected audiometric testing was originally included in the protocol of this survey. However, because of errors by an air freight company, the sound attenuating booth never arrived in the country during the time that NIOSH personnel were in the country. Proper audiometric testing of the workers is needed before embarking on the drafting of regulations

and guidelines for a hearing conservation program. The Ministry should investigate ways in which they can purchase a sound attenuating chamber for this type of testing. Currently, no such piece of equipment exists on the island. If the chamber and audiometric test equipment can be obtained, then baseline audiometry should be conducted on all St. Lucian workers, particularly those in the noisier industries. In those industries where there appears to be noise induced hearing handicap, the workers should be trained in hearing conservation and in the use of personal protective devices. Additionally, these workers should be included in periodic audiometric testing to insure that the hearing losses are not progressing at an unacceptable rate.

3. Academic programs concerning hearing, auditory anatomy and physiology, and hearing loss should be developed for inclusion in the school's science curriculum. Several instances of very loud noise exposures were observed during the survey in recreational and industrial situations that could have been avoided if the people were aware of the effects of noise on hearing. The school system of this country is very impressive in that all children attend classes until a certain age. Knowledge about the problems associated with hearing loss may increase awareness of industrial and recreational noise and help to alleviate it.

4. Copies of this report should be posted in an accessible location at each of the surveyed industries for the purpose of informing the affected employees. The information they gain from this report may make the implementation of future hearing conservation programs easier.

5. The mandatory use of HPDs should be implemented for the production area at Winera Box Factory. The process of manufacturing corrugated cardboard is sufficiently loud to warrant hearing protection. Different types of protectors, i.e., plugs and muffs, should be purchased by the company for distribution to the employees. This distribution can be coordinated by the company's medical department so that the types of protectors being used by workers can be cataloged.

6. If any hearing conservation program is going to be implemented by the Ministry of Health, then LUCELEC is the obvious choice for the first industry to receive the program. It is by far the loudest industry surveyed by NIOSH in the country. The company should pursue other brands of hearing protection to substitute for the Bilsom® products currently being used. These HPDs do not offer enough of a margin of protection for this particular environment. Also, the construction of better sound attenuating control booths and workshop areas in each of the facilities should be considered to help to reduce the amount of noise produced by the diesel generators to which the employees are exposed.

7. Heineken Brewery is already cognizant of safety and health programs as evidenced in their rigidly enforced safety glasses program. A similar program for hearing protection should also be enforced in the bottling hall and engine room for people who must be in these two areas.

8. The smaller business surveyed, i.e., Tolyn Paper Co., Belles Fashions, N.Y. Daher Tobacco Co., and DuBoulay's Bottling Co. should purchase hearing protection devices and make them available to the employees. Whether or not the use of these devices be made mandatory depends on audiometric test results from the employees.

9. In two of the surveyed industries, unsafe work practices were observed during the noise sampling. In DuBoulay's Bottling Company, a bottle exploded while being filled, spraying soda and shattered glass in the area around the filling machine. None of the employees were wearing safety glasses in the bottling room at the time of this incident. Because of the strong potential for eye injury, safety glasses should be purchased by the company and provided to the employees for mandatory wearing.

10. The housekeeping conditions in Ramco Plastics presented a safety and fire hazard as well as being unsanitary. The huge pile of waste material in the back room is a prime candidate for a fire and for rodent infestation. The storage of the company's finished product is also presenting a dangerous situation in that it showed evidence of slipping off of the storage racks and onto workers who must stand below the area. Finally, the empty cans of paints and chemicals located along one wall of the bag cutting room present both a slip and fire hazard. These situations need immediate attention to prevent injury or illness.

VIII. REFERENCES

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IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Evaluation Conducted and Report Prepared By:	Randy L. Tubbs, Ph.D. Psychoacoustician Industrial Hygiene Section
Field Assistance:	Richard A. Keenlyside, M.D. Epidemiologist CAREC
	Edward G. Emmanuel. M.P.H. Environmental Health Officer Ministry of Health - St. Lucia
	Harold Andrew Environmental Health Officer Ministry of Health - St. Lucia
	David Joseph Environmental Health Officer Ministry of Health - St. Lucia
	Lesmond Magloire Environmental Health Officer Ministry of Health - St. Lucia
	Barnabus Annius Labor Inspector Ministry of Labour - St. Lucia

Originating Office: Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations, and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio

Report Typed By: Linda Morris
Clerk-Typist
Industrial Hygiene Section

X. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Ministry of Health, Housing and Labour, Castries, St. Lucia W.I.
2. Caribbean Epidemiology Centre, Port of Spain, Trinidad W.I.

TABLE 2

Results of Personal Noise Dosimetry
Winera Box Plant

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

Job Description/Area	Avg. 8-hr TWA dB(A)	Range dB(A)
Corrugated Box Machine	94.4	90.2 - 98.4
Folding Box Machine	92.1	89.7 - 94.0
Waste Clean-Up	89.8	88.5 - 91.0
ZLG Machine	90.9	N/A
Forklift Operator	90.3	N/A
Boiler Room Operator	83.4	N/A

NIOSH and ACGIH Criteria = 85 dB(A)
OSHA Regulation = 90 dB(A)

N/A - not applicable

TABLE 1

Results of Personal Noise Dosimetry

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

Company	Date of Testing	Number of Samples	Avg. Sample Period	Avg. 8-hr TWA*	Range*
Winera Box	11/3/87	11	406 min	92 dB(A)	83-98 dB(A)
LUCELEC - Vieux Fort	11/3/87	3	402 min	96 dB(A)	91-99 dB(A)
Belles Fashions	11/4/87	6	419 min	84 dB(A)	82-89 dB(A)
Tolyn Paper	11/4/87	4	427 min	86 dB(A)	83-88 dB(A)
Heineken	11/5/87	8	435 min	88 dB(A)	81-93 dB(A)
NEHOC Gloves	11/5/87	3	427 min	82 dB(A)	77-85 dB(A)
Data Delay Devices	11/5/87	2	408 min	73 dB(A)	73-74 dB(A)
LUCELEC - Union Sta.	11/9/87	13	439 min	102 dB(A)	88-106 dB(A)
N.Y. Daher Tobacco Co.	11/10/87	7	177 min	88 dB(A)	86-89 dB(A)
Ramco Plastics	11/11/87	8	429 min	85 dB(A)	79-92 dB(A)
DuBoulay's Bottl. Co.	11/12/87	5	427 min	89 dB(A)	85-92 dB(A)
Government Printery	11/12/87	6	406 min	82 dB(A)	77-89 dB(A)

NIOSH and ACGIH Criteria = 85 dB(A)
OSHA Regulation = 90 dB(A)

* All TWA values calculated according to U.S. Department of Labor's OSHA Regulation stipulating a 5 dB time/intensity trading relationship.

TABLE 3

Results of Personal Noise Dosimetry
LUCELEC

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

Job Description/Area	Avg. 8-hr TWA dB(A)	Range dB(A)
Power Plant Operators	101.3	95.1 - 105.9
Mechanics	100.8	90.9 - 104.2
Waste Clean-Up	94.4	94.3 - 94.4
Electricians	91.0	N/A

NIOSH and ACGIH Criteria = 85 dB(A)
OSHA Regulation = 90 dB(A)

N/A - not applicable

TABLE 4

Results of Area Sound Level Measurements
(all values are reported in decibels)

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

	Octave Band Center Frequency (Hz)									Overall Weighted Level	
Location	31.5	63	125	250	500	1k	2k	4k	8k	16k	C	A
Front #1 Generator	91	95	98	99	102	101	101	101	102	90	109	108
Front #3 Generator	91	94	100	100	102	101	101	101	101	91	109	108
Desk; Control Room	84	83	88	84	82	78	78	77	74	60	92	85

TABLE 5

Attenuation Data for Hearing Protection Devices (HPD) used at LUCELEC
(all values are reported in decibels)

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

HPD		Band Center Frequency (Hz) 125	250	500	1k	2k	3k	4k	6k	8k
Bilsom Propp-O-Plast ear plugs	Mean Value	23	25	26	26	34	39	41	41	38
	1 Std. Deviation	3.6	2.8	2.5	3.0	3.0	2.2	2.8	3.2	3.6
Bilsom UF-2 ear muffs	Mean Value	12	15	25	35	37	39	37	37	34
	1 Std. Deviation	2.1	1.4	1.6	2.2	1.9	2.3	1.8	2.3	1.6

TABLE 6

Results of Personal Noise Dosimetry
Heineken Brewery

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

Job Description/Area	Avg. 8-hr TWA dB(A)	Range dB(A)
Bottling Hall	89.9	87.3 - 92.8
Brew House	81.3	80.8 - 81.8
Engine Room	85.4	84.1 - 86.5
Fork Lift Operator	87.9	N/A

NIOSH and ACGIH Criteria = 85 dB(A)
OSHA Regulation = 90 dB(A)

N/A - not applicable

TABLE 7

Results of Personal Noise Dosimetry
Ramco Plastics Co.

Ministry of Health
St. Lucia, West Indies

HETA 87-413
November 1-14, 1987

Job Description/Area	Avg. 8-hr TWA dB(A)	Range dB(A)
Plastic Film Production	88.3	88.3 - 88.3
Plastic Bag Cutters	80.7	79.3 - 81.8
Material Handler	80.8	N/A
Material Recycle	91.7	N/A

NIOSH and ACGIH Criteria = 85 dB(A)
OSHA Regulation = 90 dB(A)

N/A - not applicable

APPENDIX A

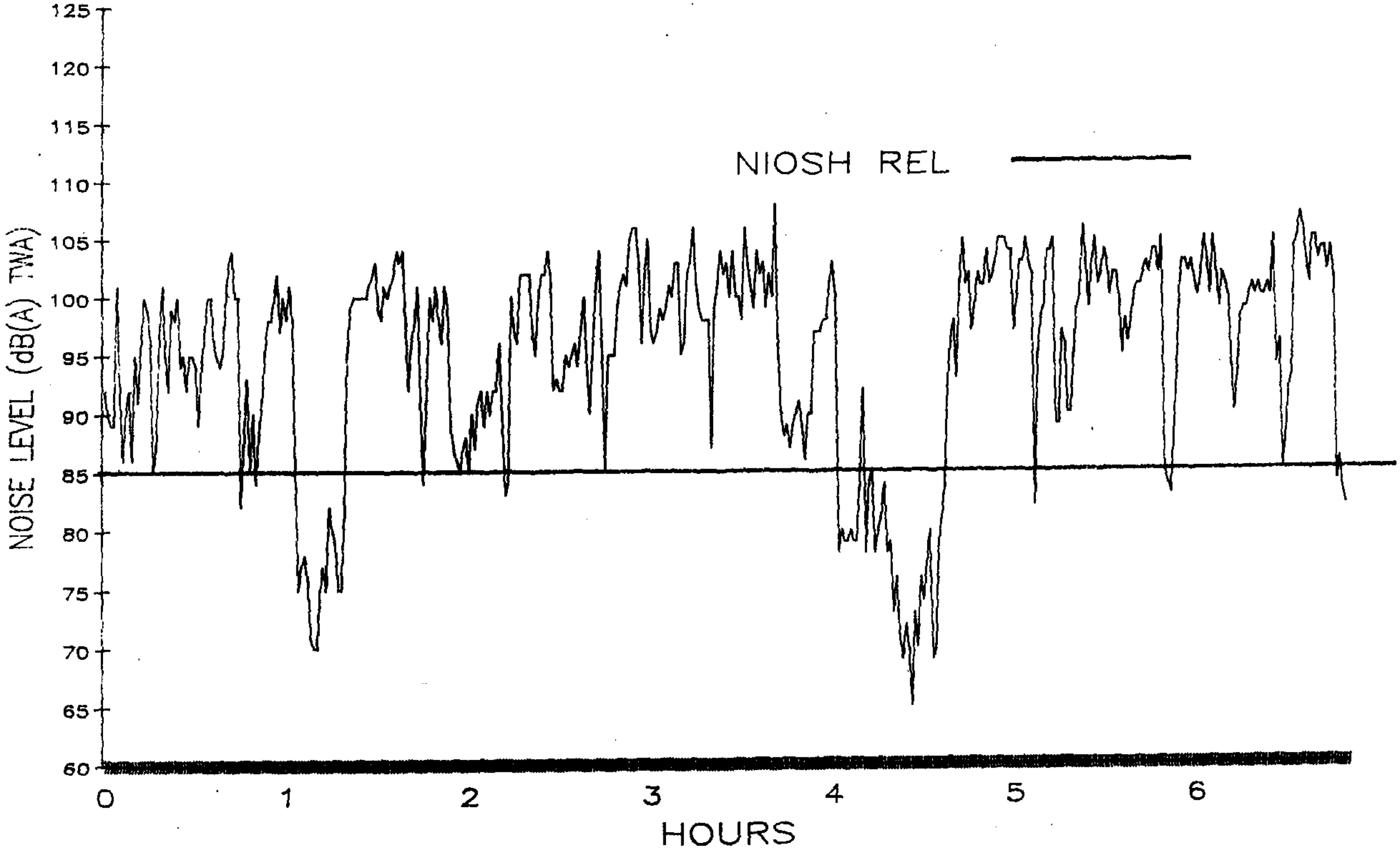
Metrosonics, Inc. 301-db Metrologger Readouts from Individual Workers of the Surveyed Industries

HETA 87-413

St. Lucia Noise Survey

Winera Box Factory

Corrugated Box Machine - Front End

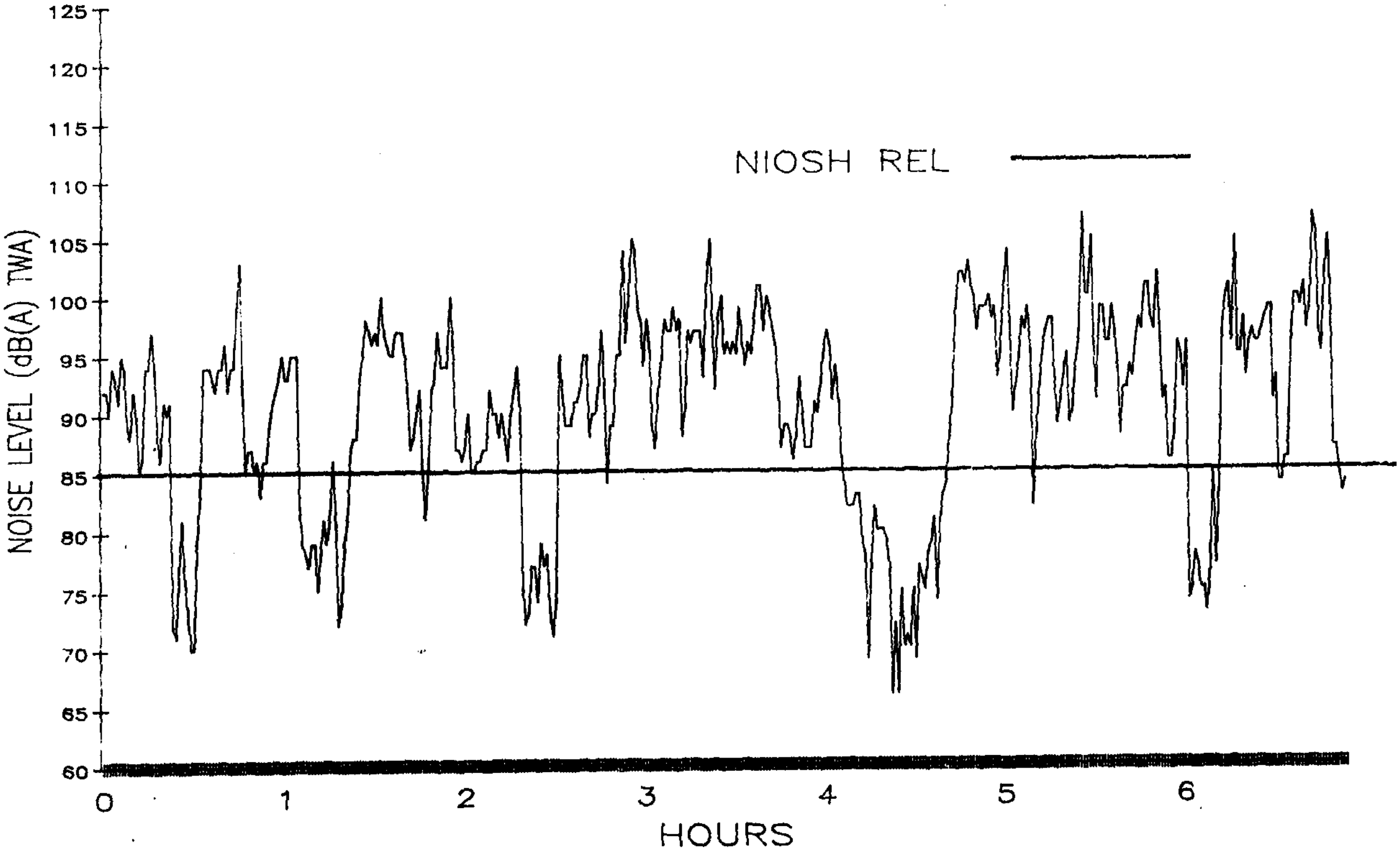


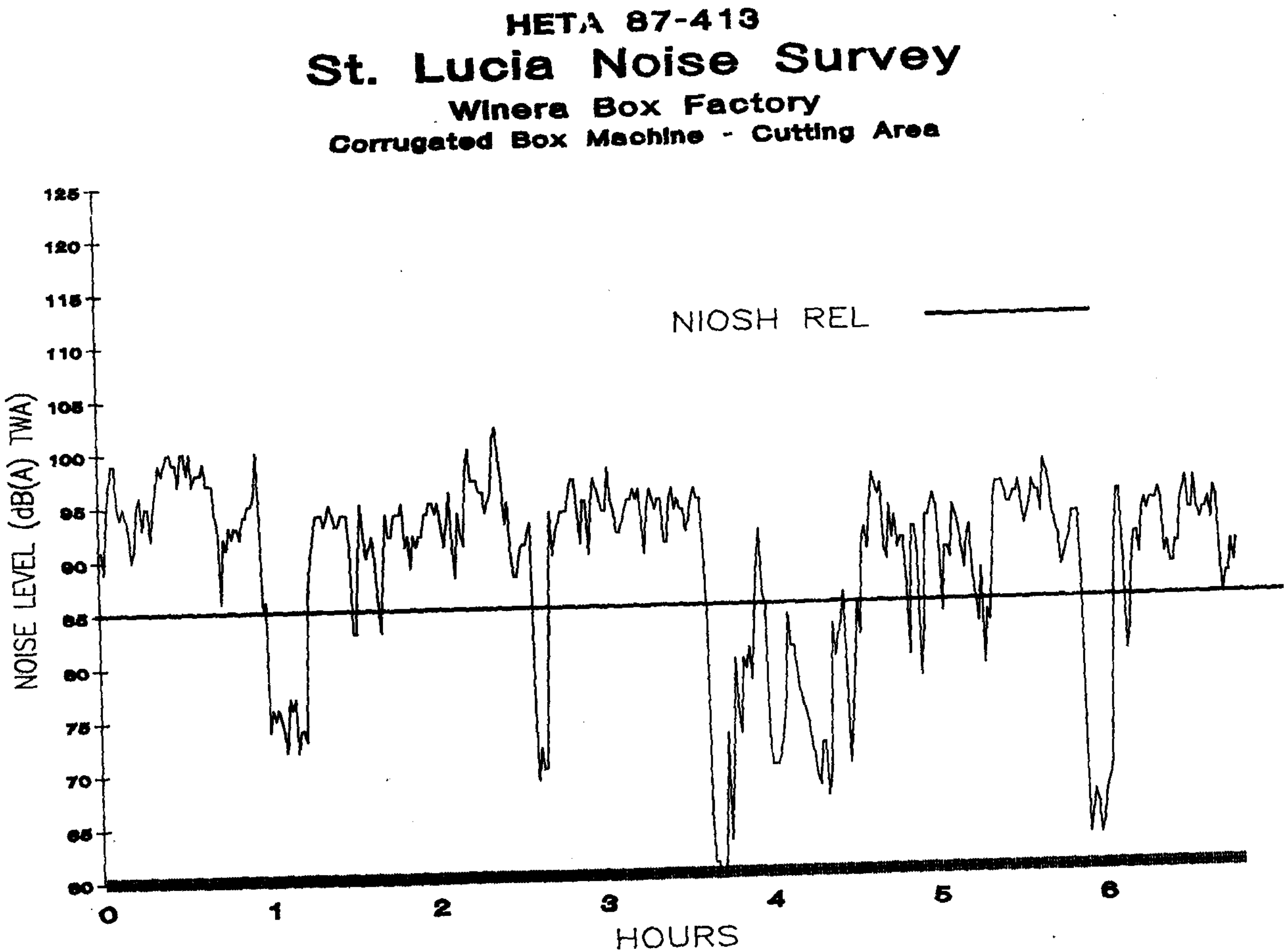
HETA 87-413

St. Lucia Noise Survey

Winera Box Factory

Corrugated Box Machine - Middle of Machine



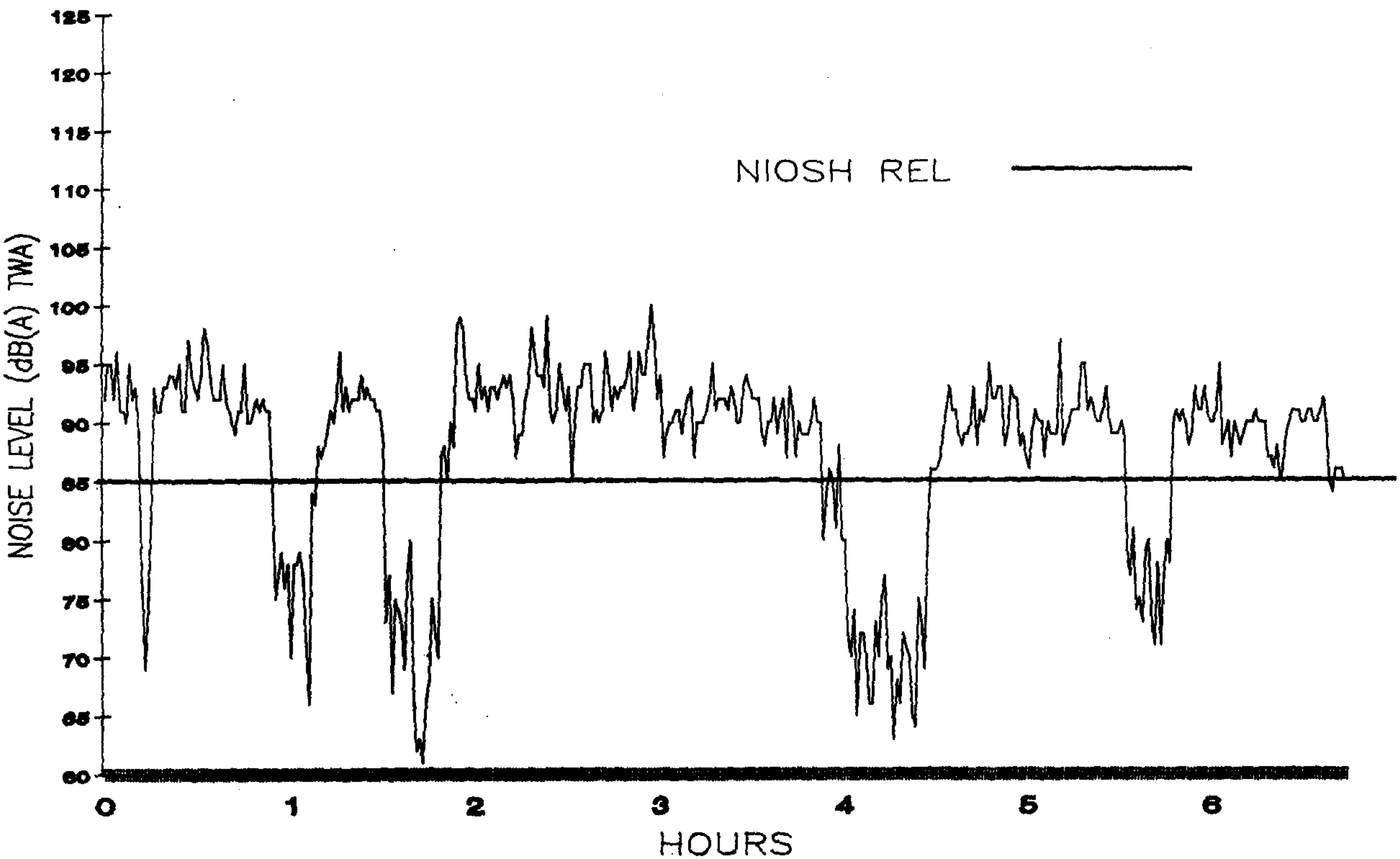

HETA 87-413
St. Lucia Noise Survey
Winera Box Factory
Corrugated Box Machine - Cutting Area
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
HOURS

HETA 87-413

St. Lucia Noise Survey

Winera Box Factory

Corrugated Box Machine - Take Off & Stacking

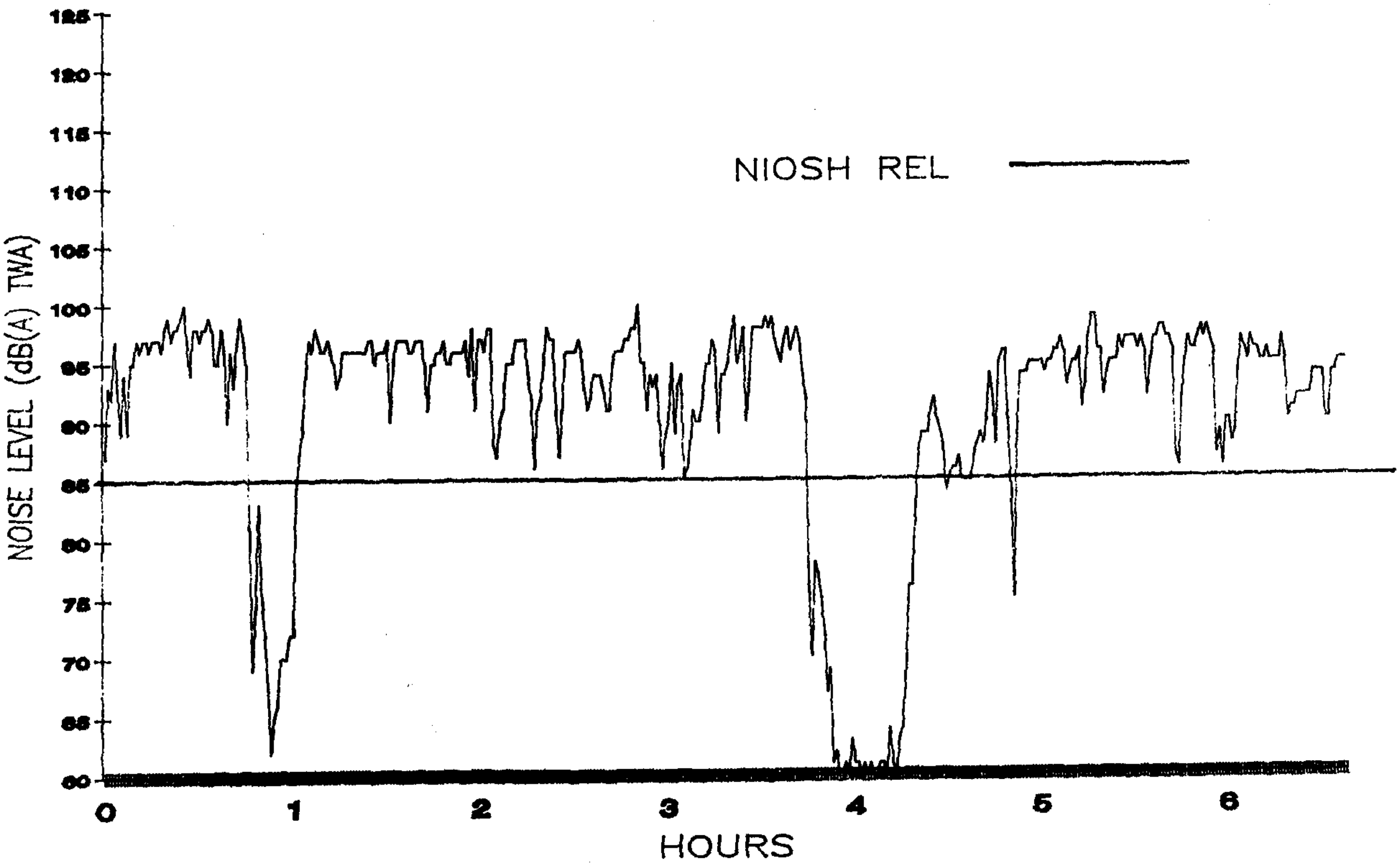


HETA 87-413

St. Lucia Noise Survey

Winera Box Factory

Box Folding Machine - Feed End

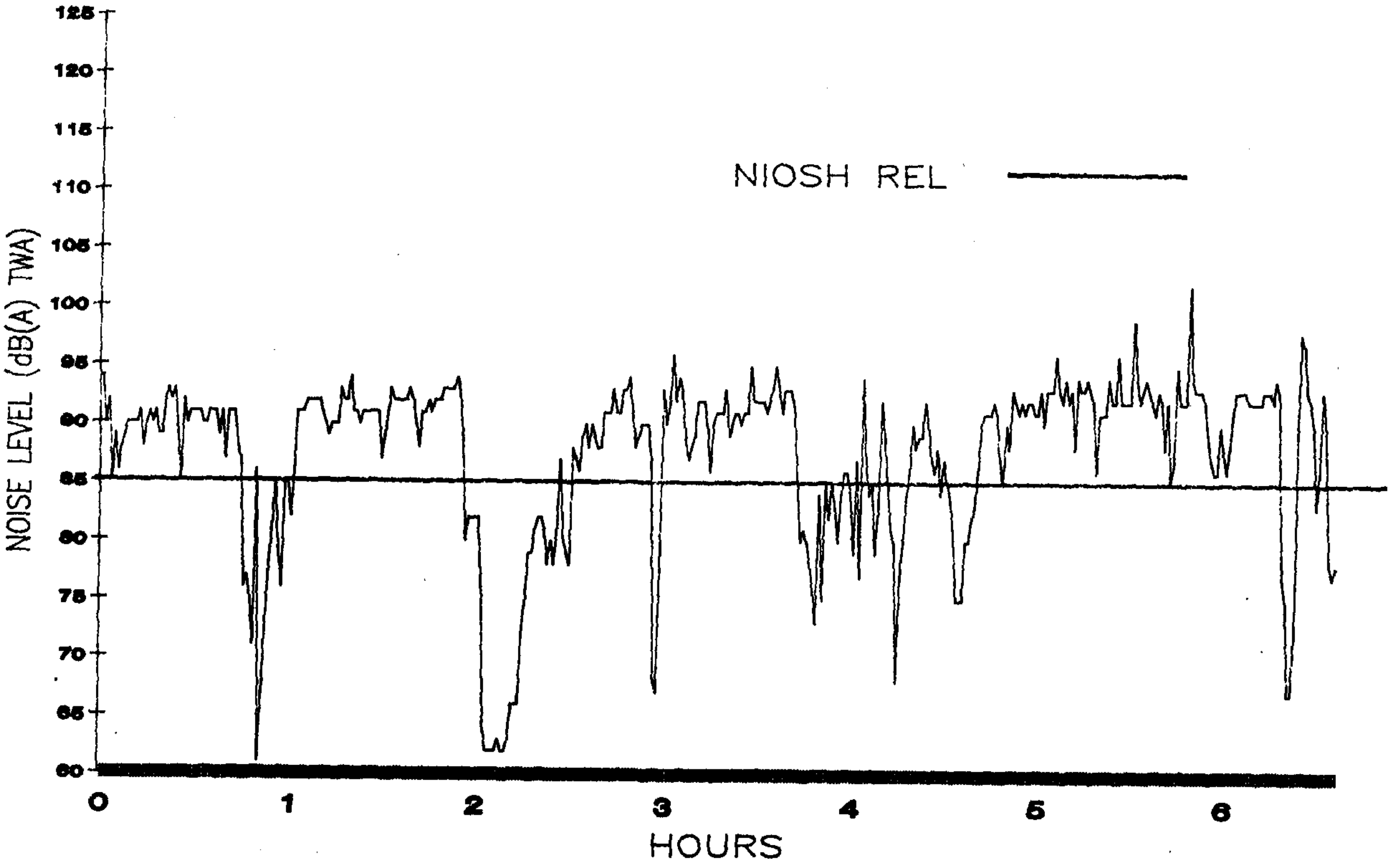


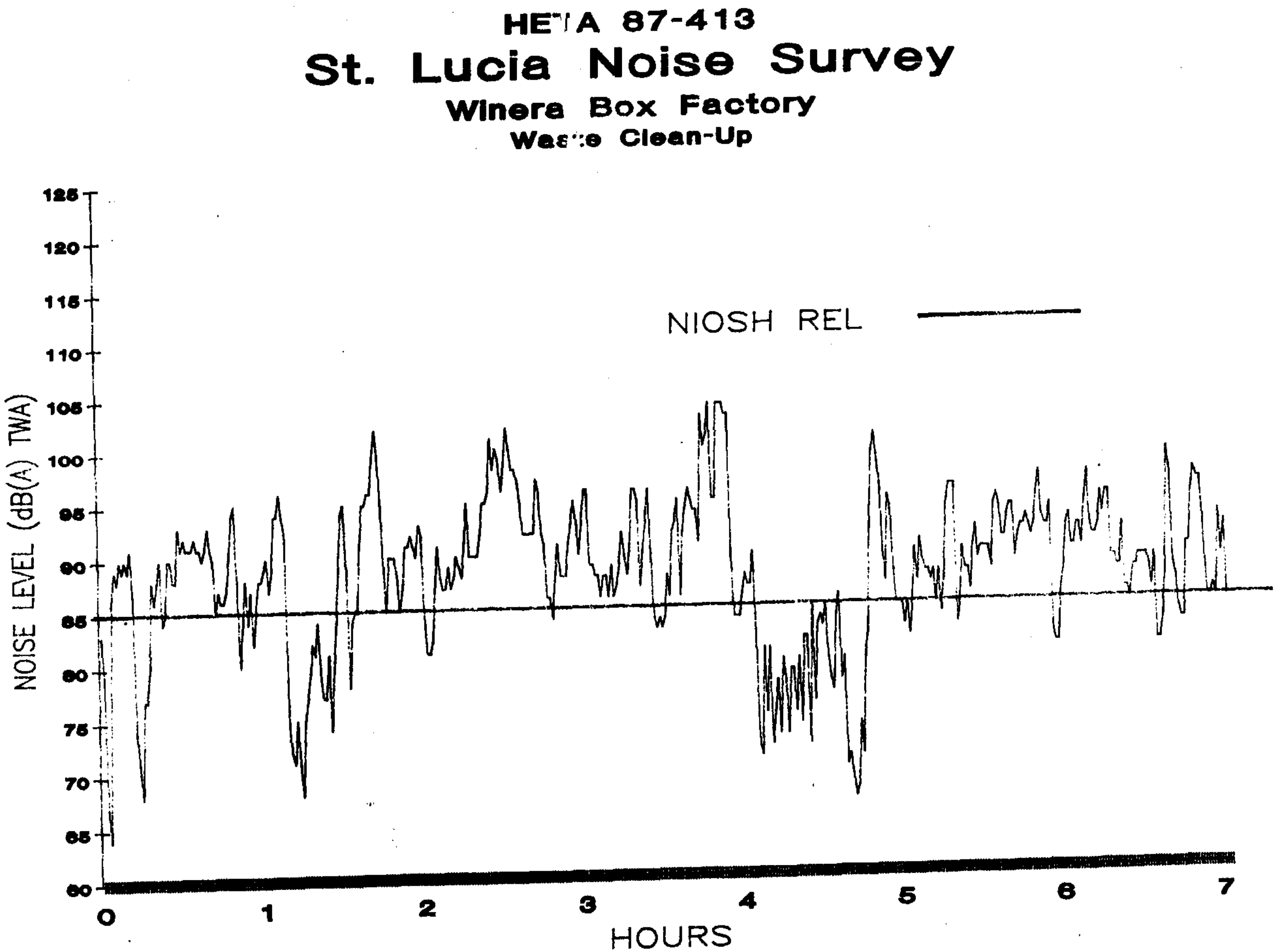
HETA 87-413

St. Lucia Noise Survey

Winera Box Factory

Box Folding Machine - Take-Off End



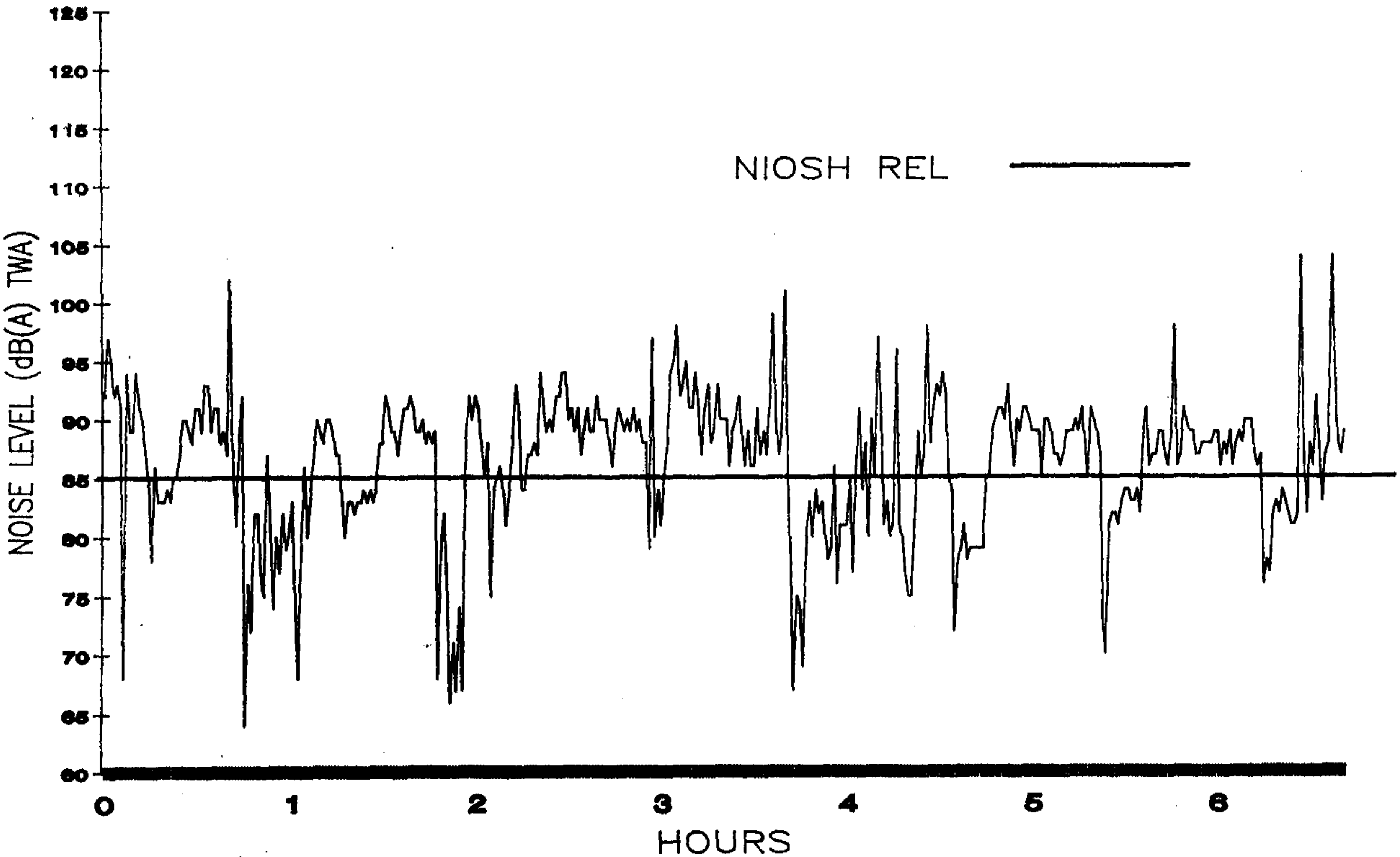

HETA 87-413
St. Lucia Noise Survey
Winera Box Factory
Waste Clean-Up
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
HOURS

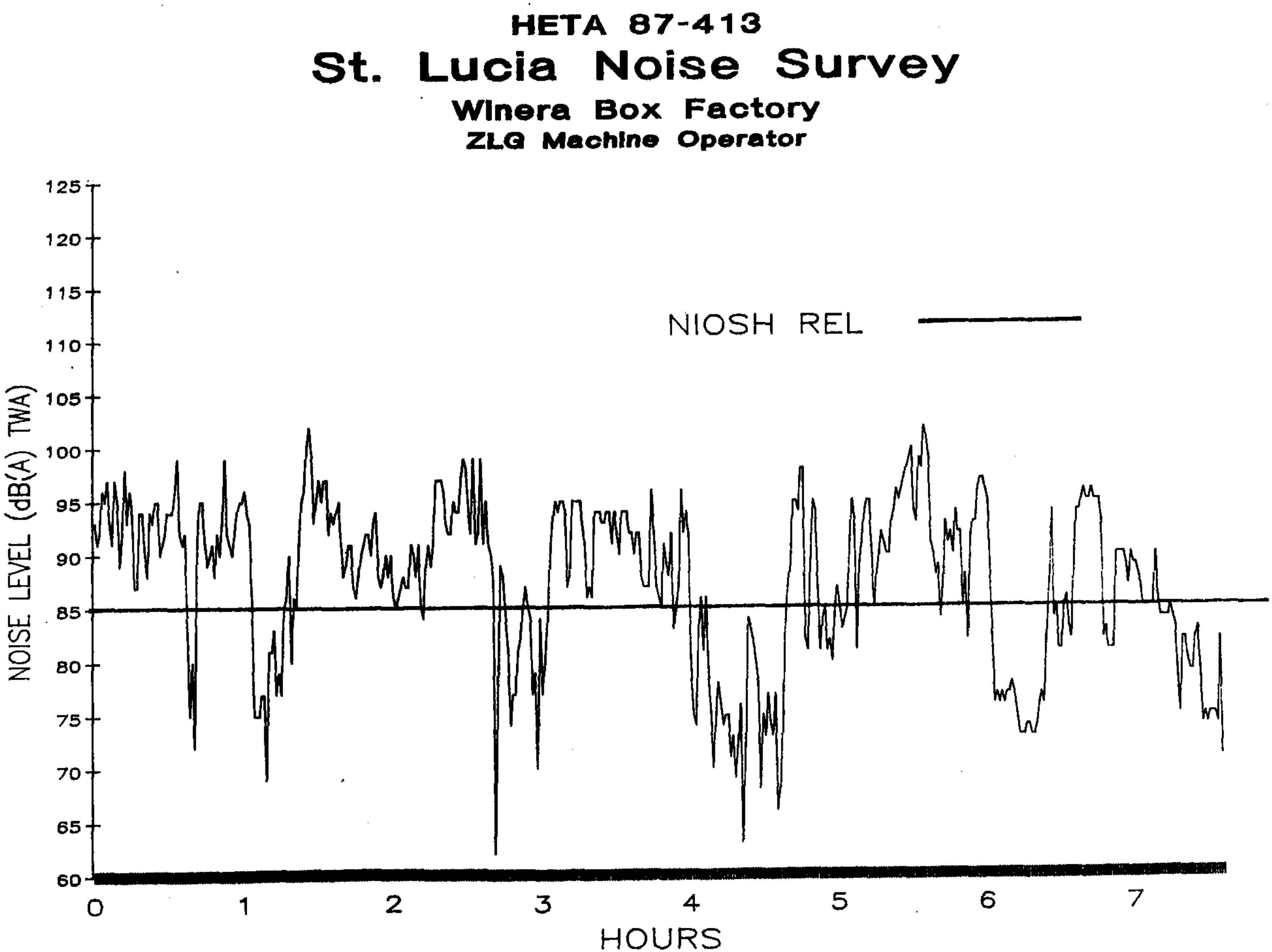
HETA 87-413

St. Lucia Noise Survey

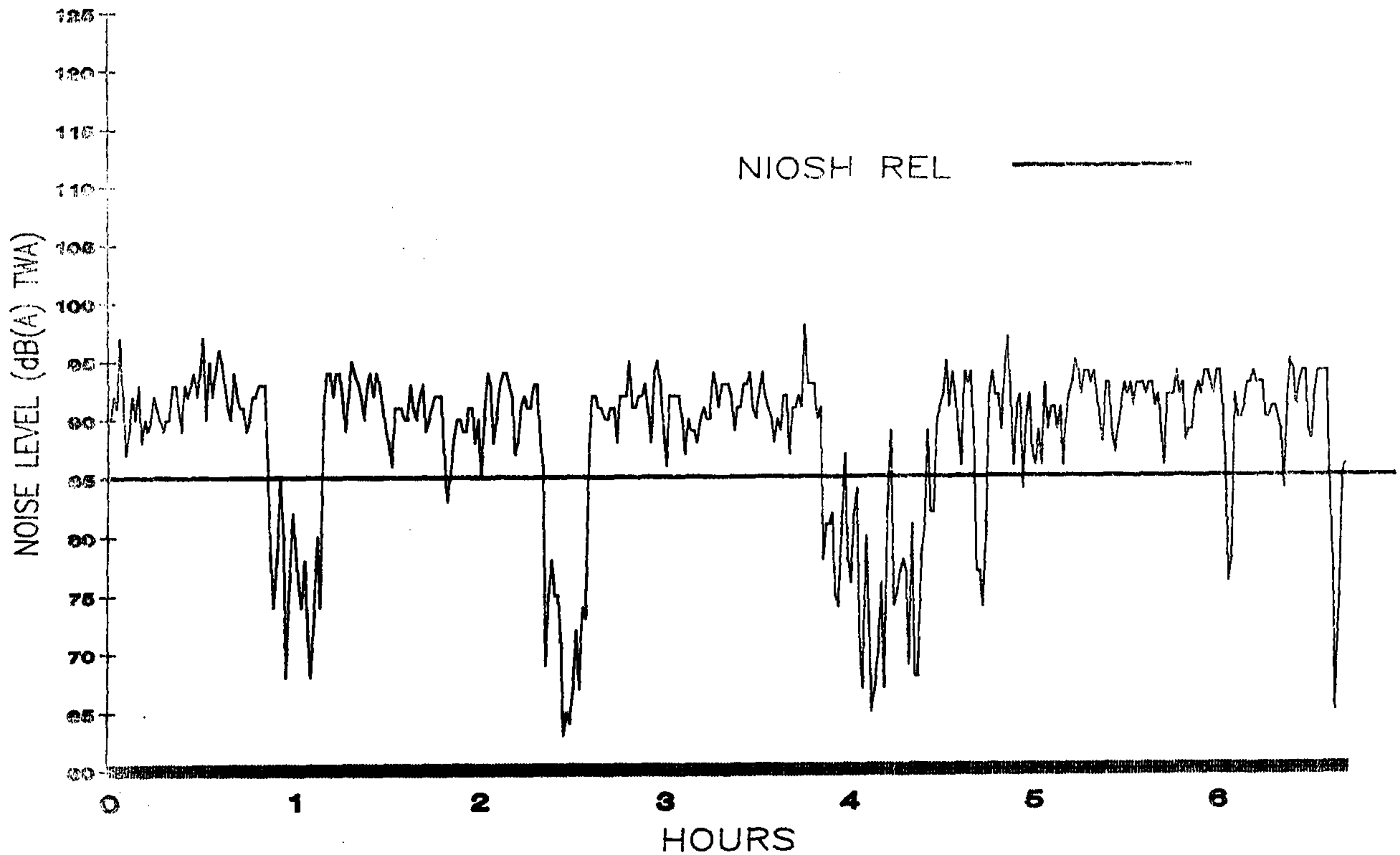
Winera Box Factory

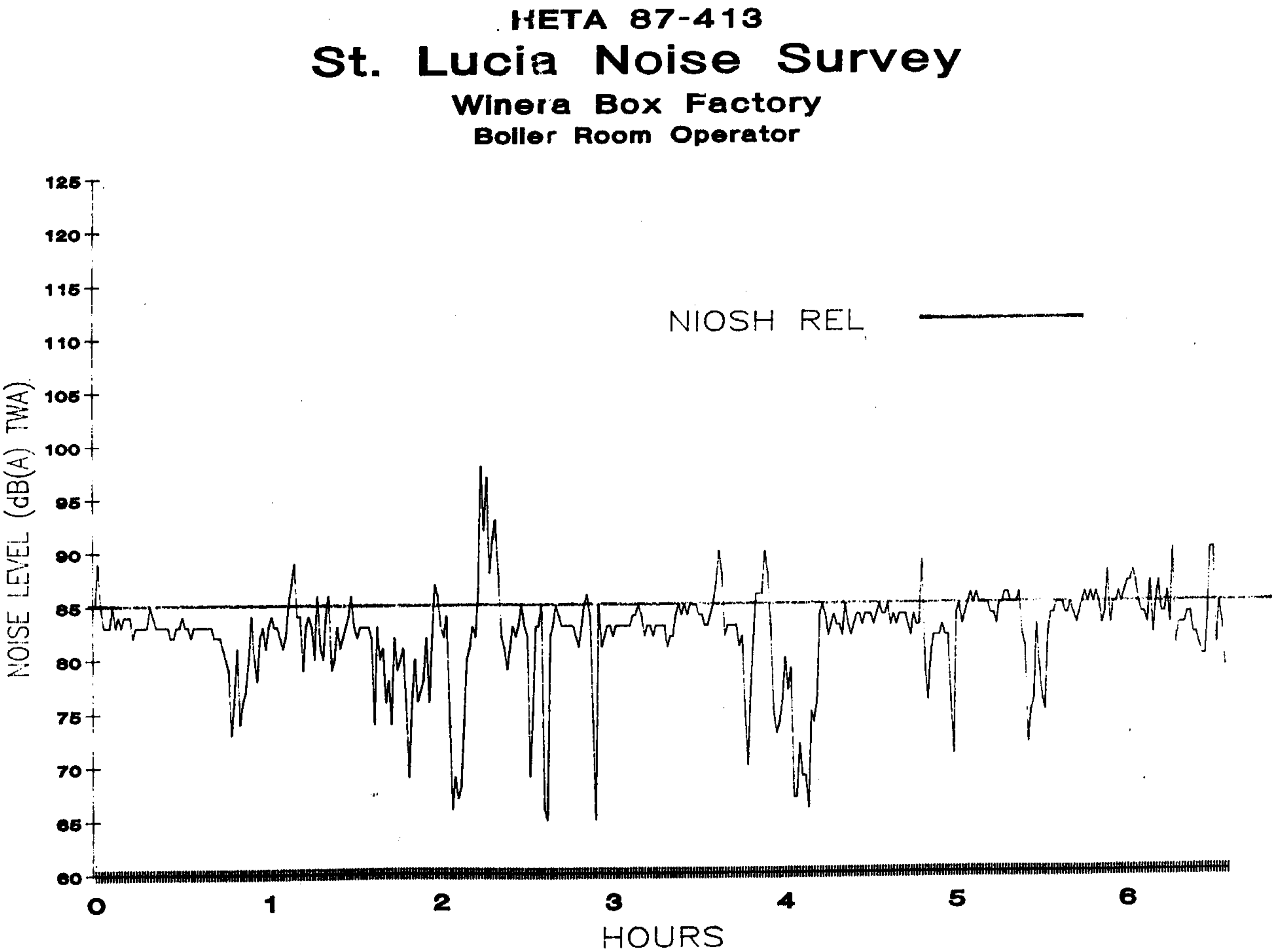
Waste Compactor Area




HETA 87-413
St. Lucia Noise Survey
Winera Box Factory
ZLG Machine Operator
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
HOURS

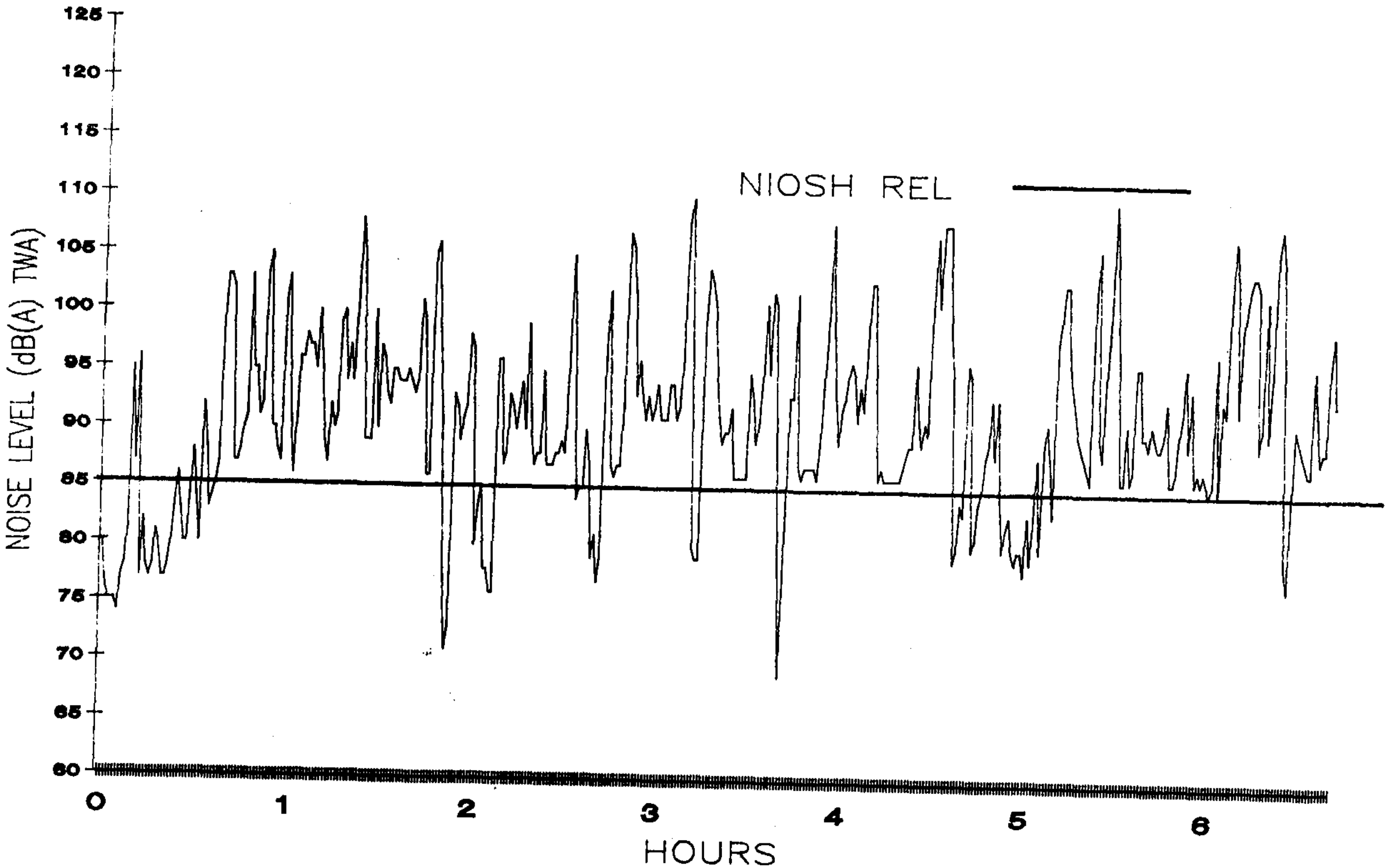
HETA 87-413
St. Lucia Noise Survey
Winera Box Factory
Fork Lift Operator





HETA 87-413
St. Lucia Noise Survey
Winera Box Factory
Boiler Room Operator
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
HOURS

HETA 87-413
St. Lucia Noise Survey
LUCELEC - Vieux Fort Station
Power Plant Operator

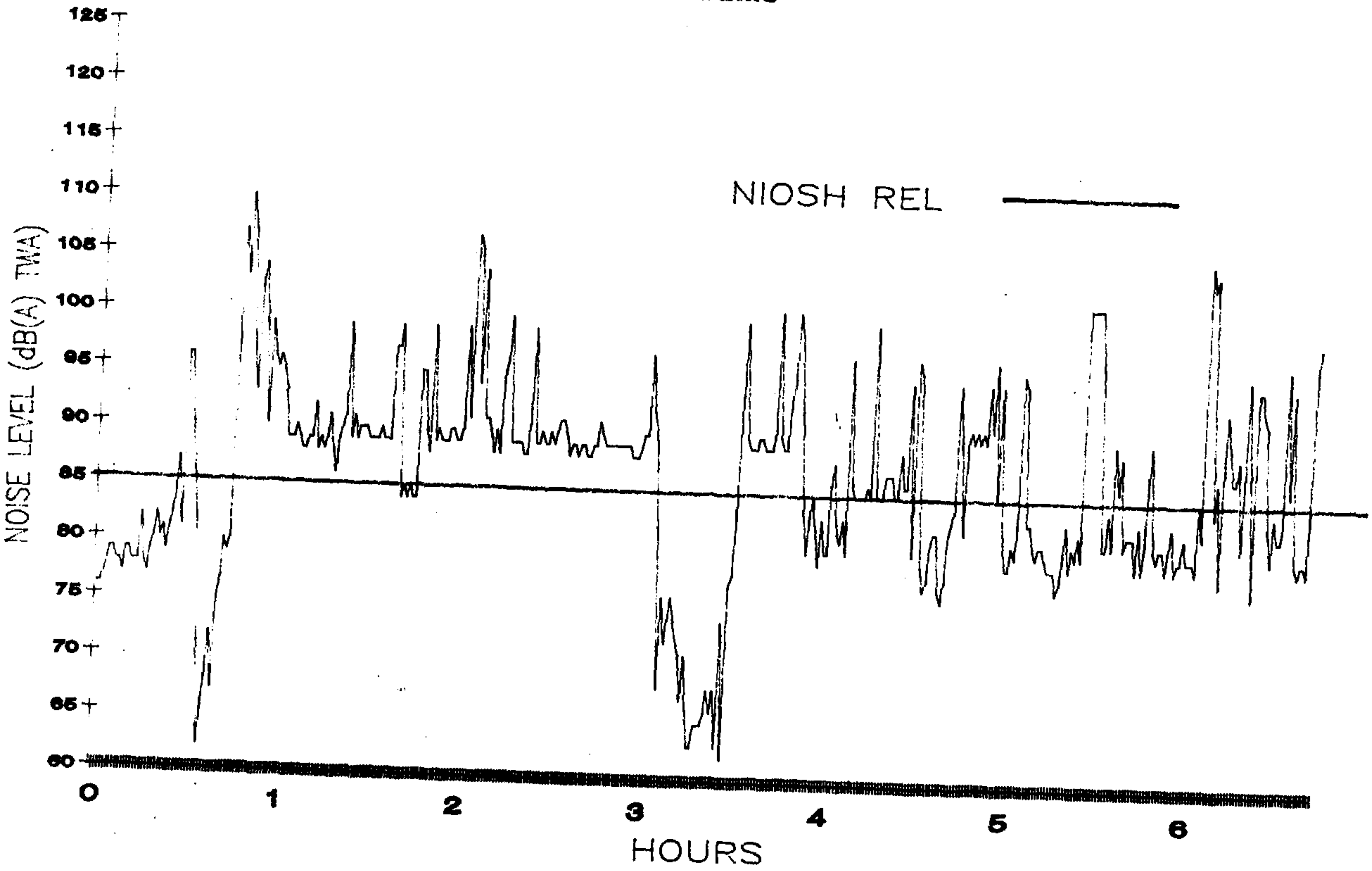


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Vieux Fort Station

Mechanic

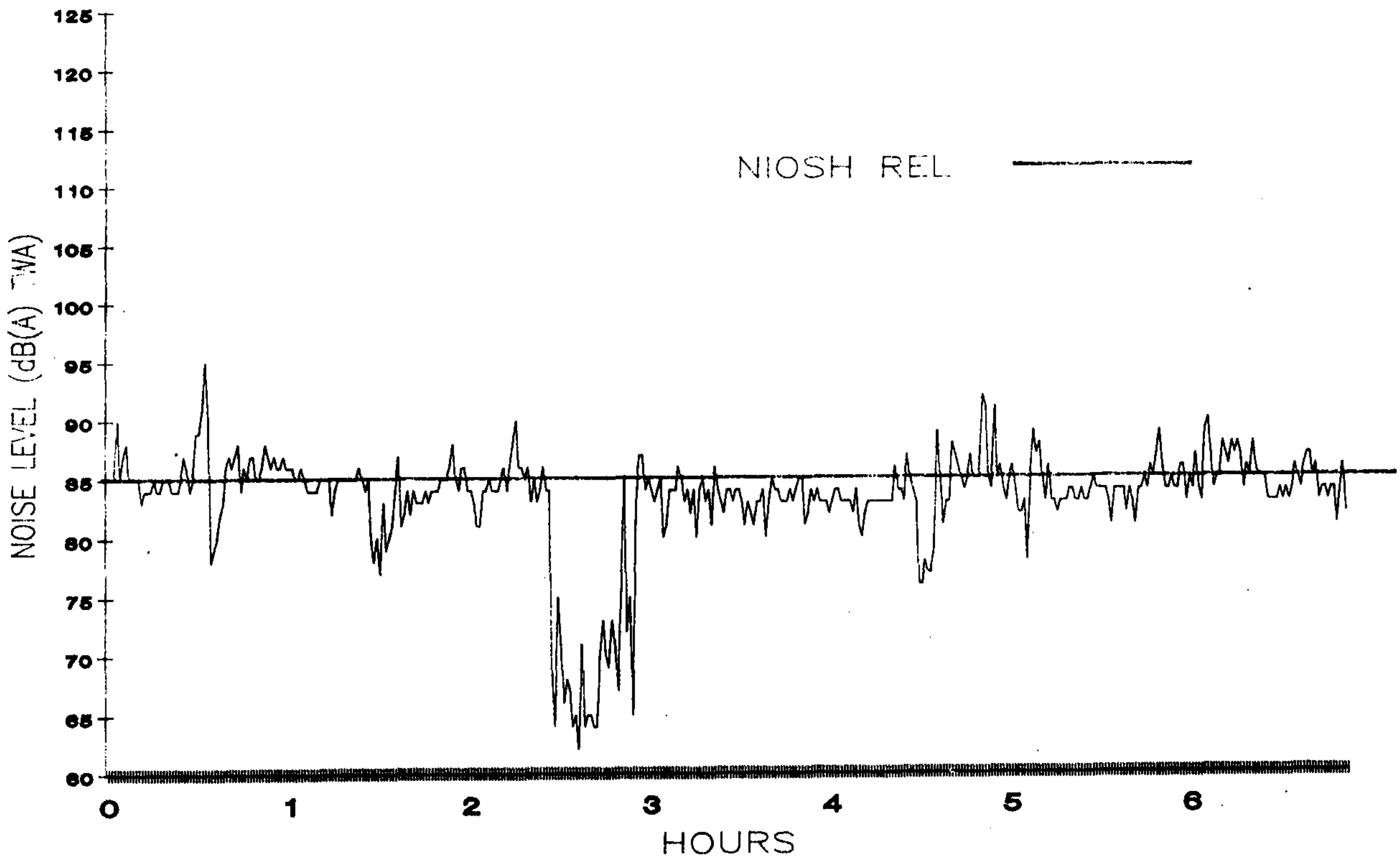


HETA 87-413

St. Lucia Noise Survey

Belles Fashions

Tacking Section - New Machine

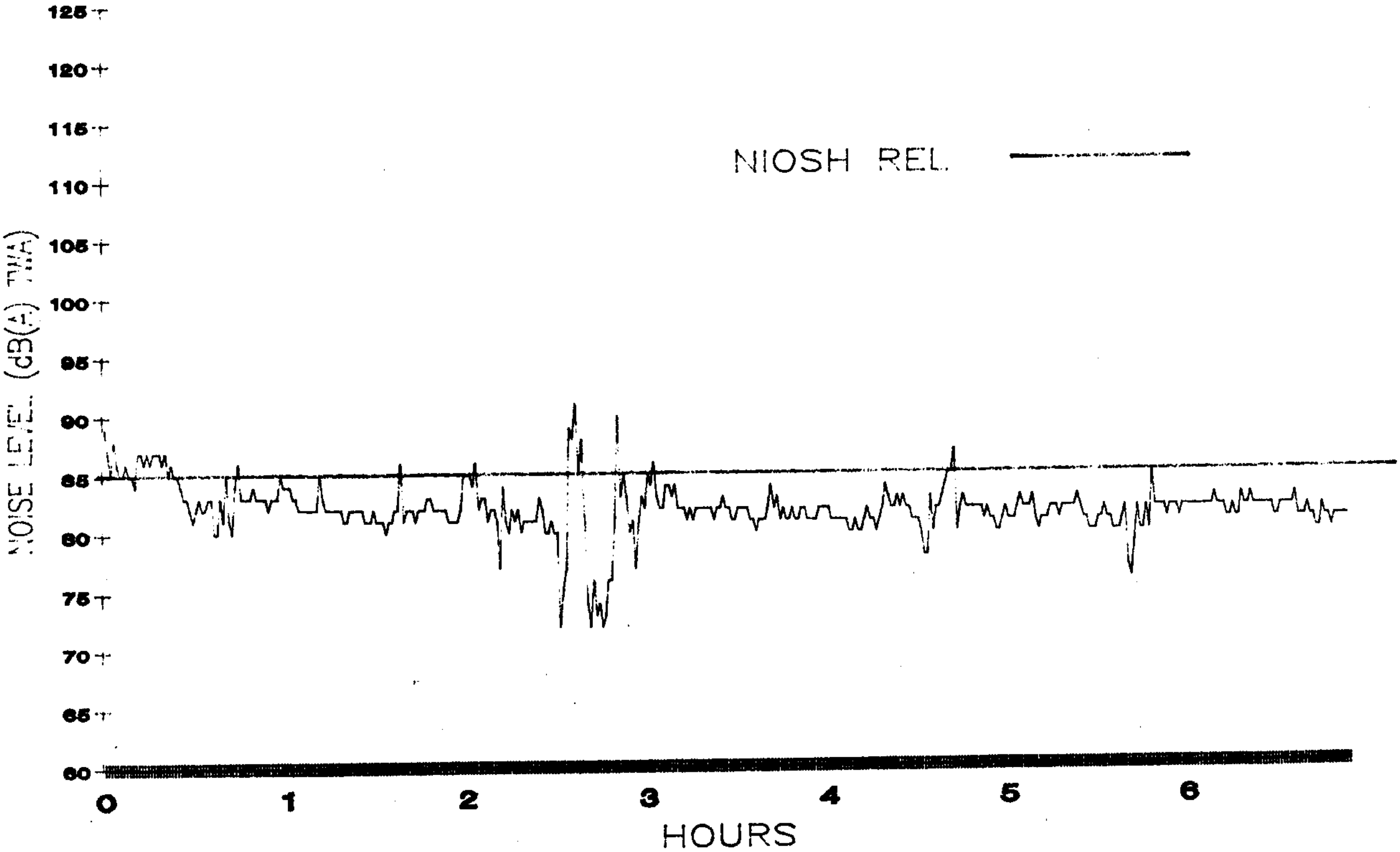


HETA 87-413

St. Lucia Noise Survey

Belles Fashions

Free Stitching on Top of Bra

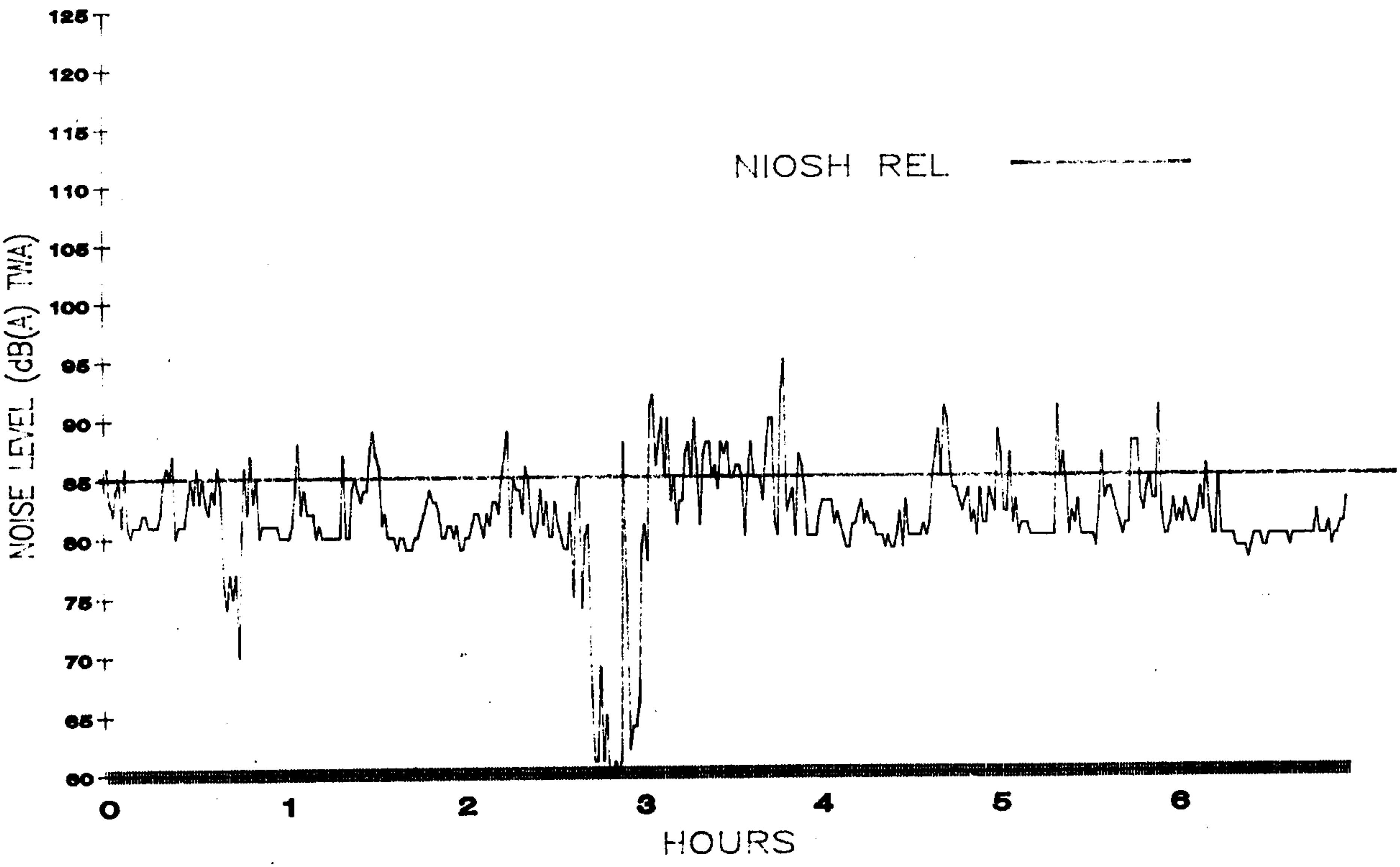


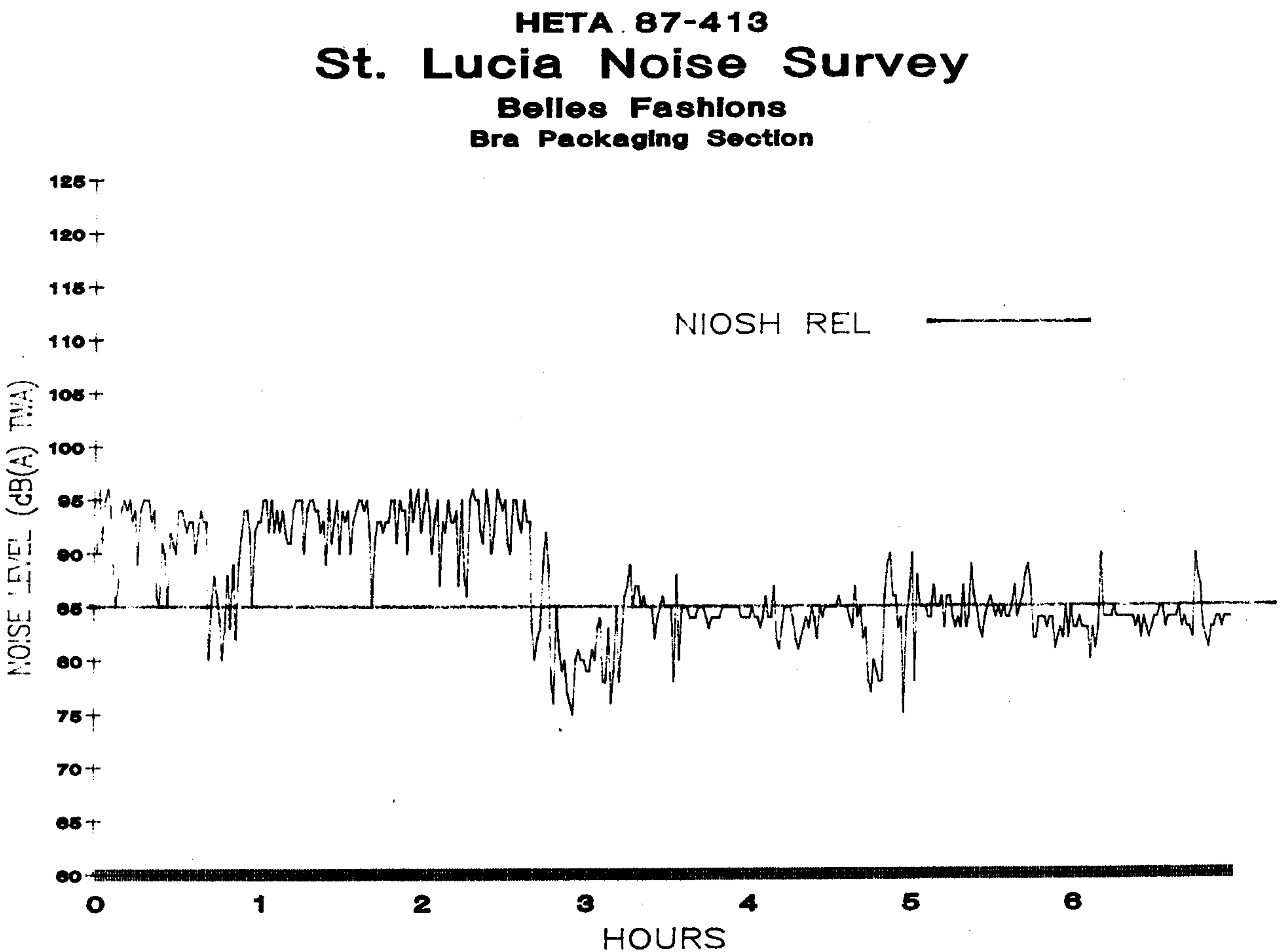
HETA 87-413

St. Lucia Noise Survey

Belles Fashions

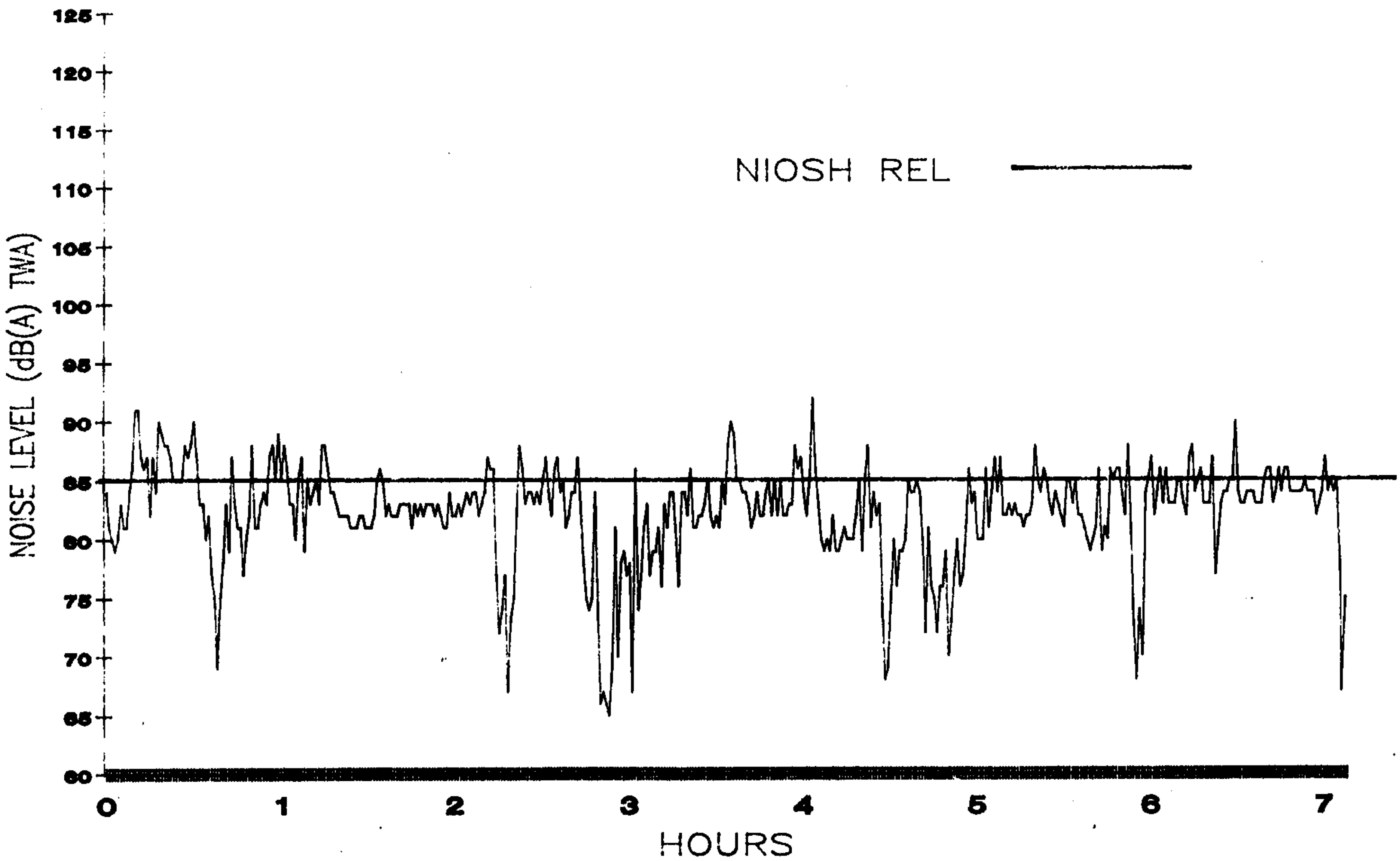
Main Sewing Area - Old Machine





HETA 87-413
St. Lucia Noise Survey
Belles Fashions
Bra Packaging Section
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
HOURS

HETA 87-413
St. Lucia Noise Survey
Belles Fashions
Floor Supervisor

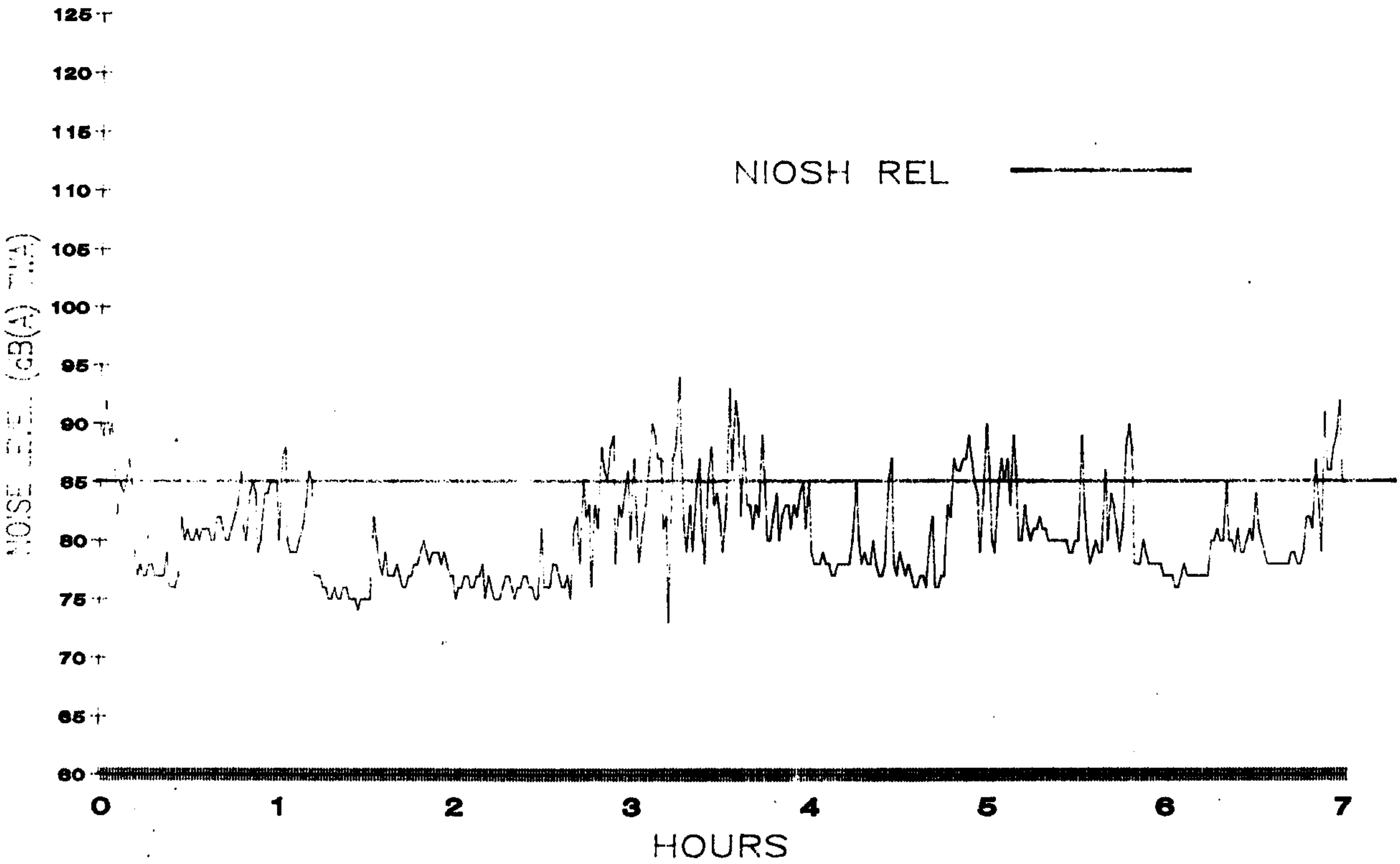


HETA 87-413

St. Lucia Noise Survey

Belles Fashions

Finishing Area

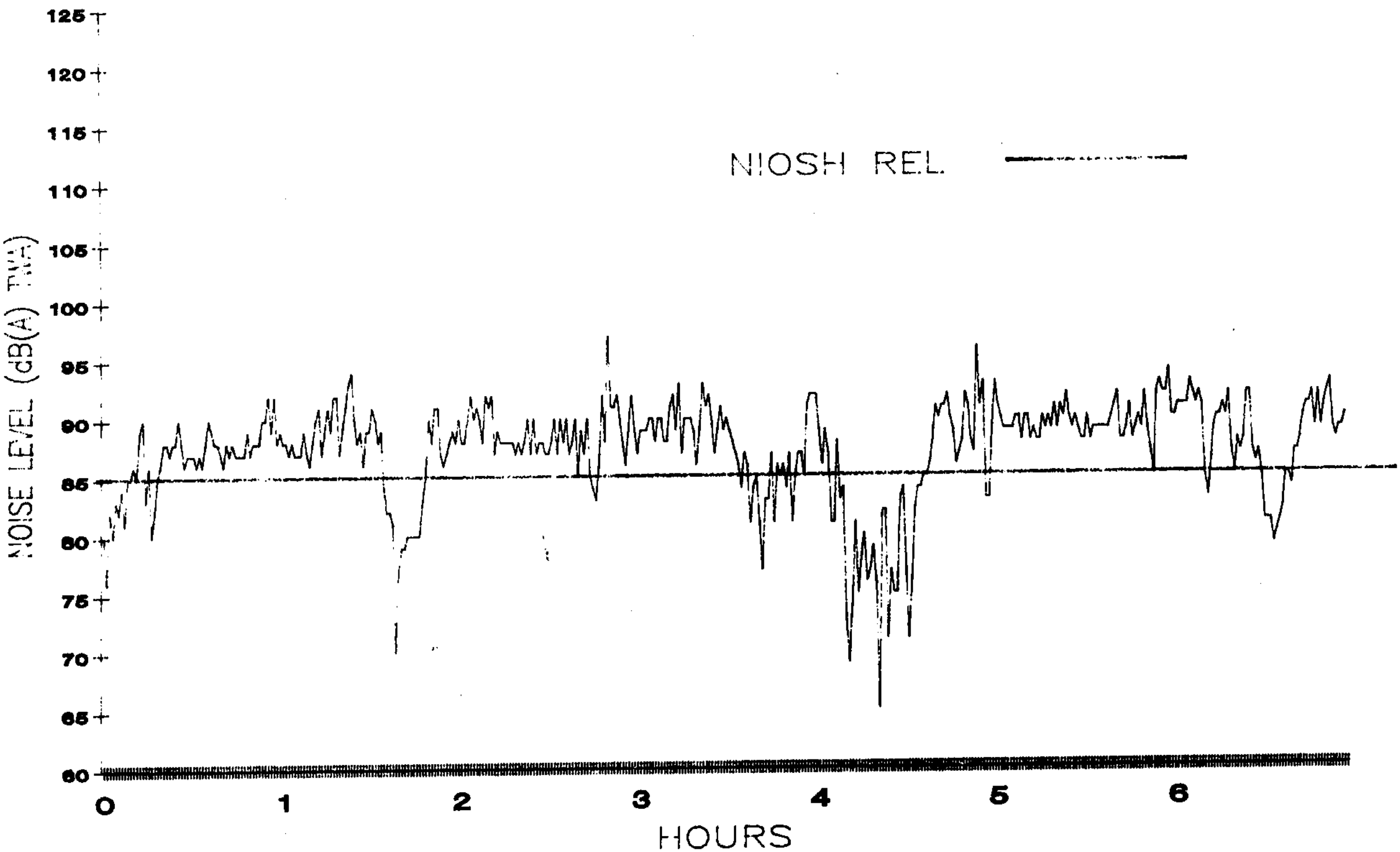


HETA 87-413

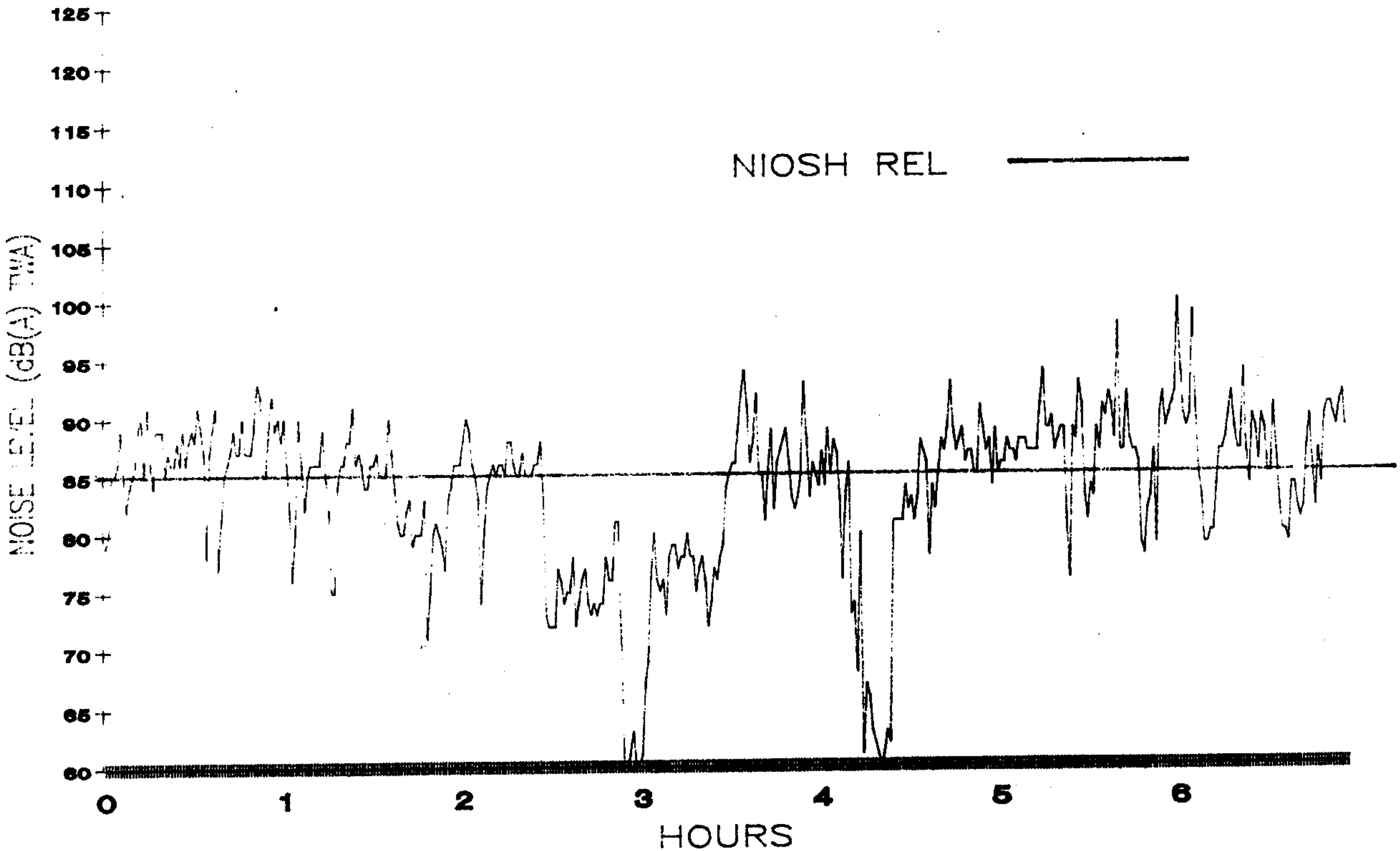
St. Lucia Noise Survey

Tolyn Paper Company

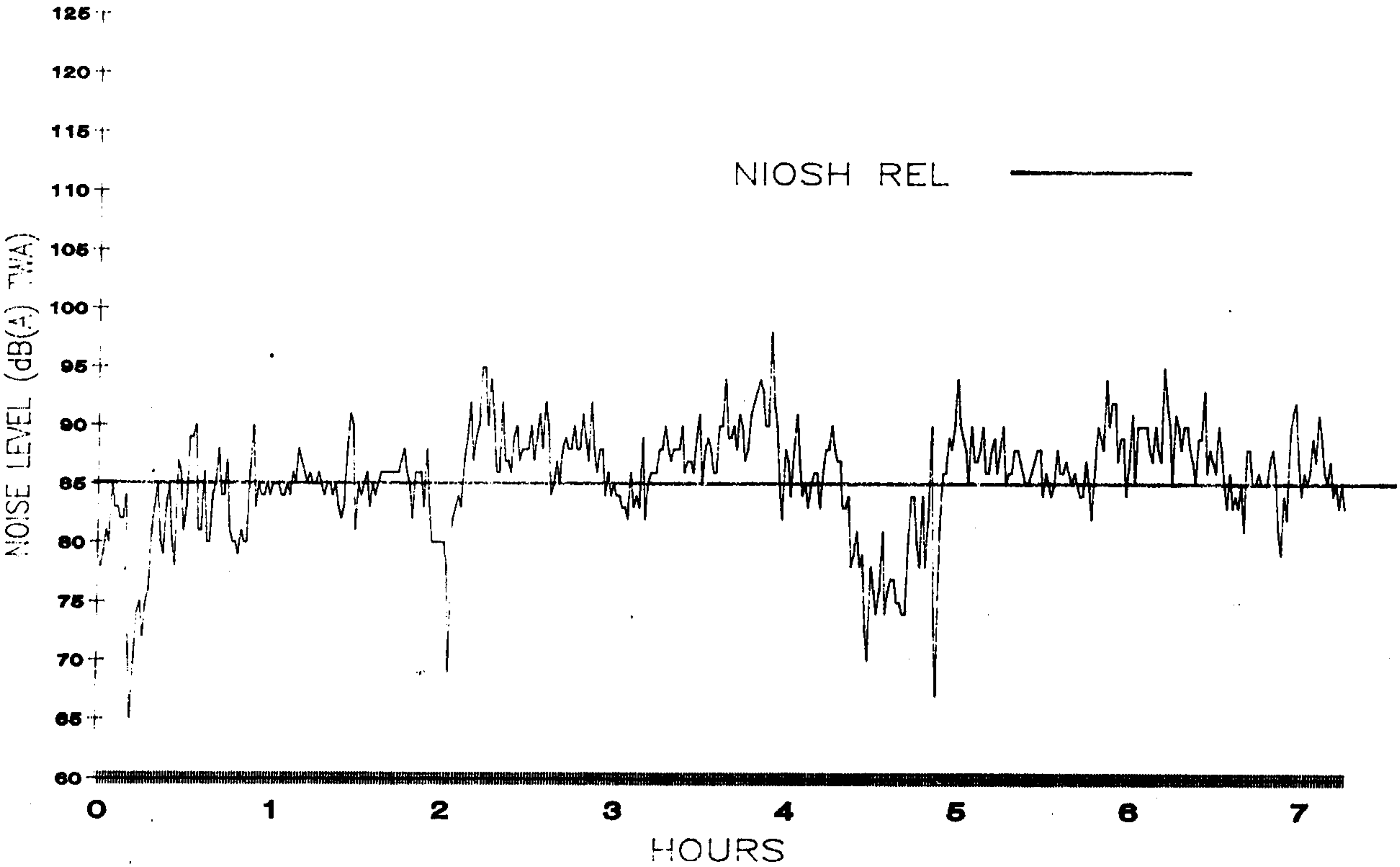
Toilet Paper Rolling Machine



HETA 87-413
St. Lucia Noise Survey
Tolyn Paper Company
Toilet Paper Roll Cutting Machine



HETA 87-413
St. Lucia Noise Survey
Tolyn Paper Company
Toilet Paper Roll Packer



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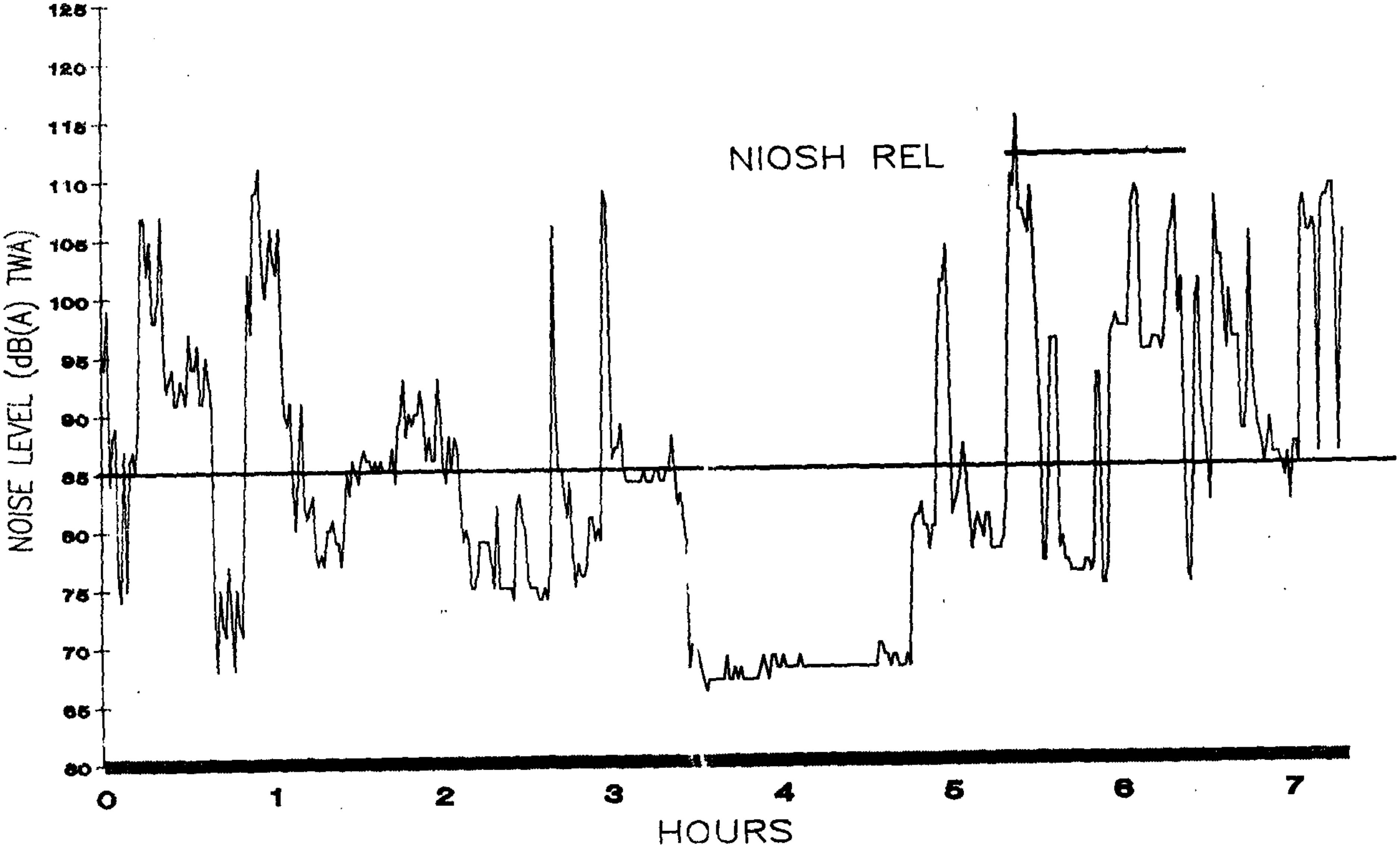
St. Lucia Noise Survey
LUCELEC - Union Station
Waste Clean-Up "B"

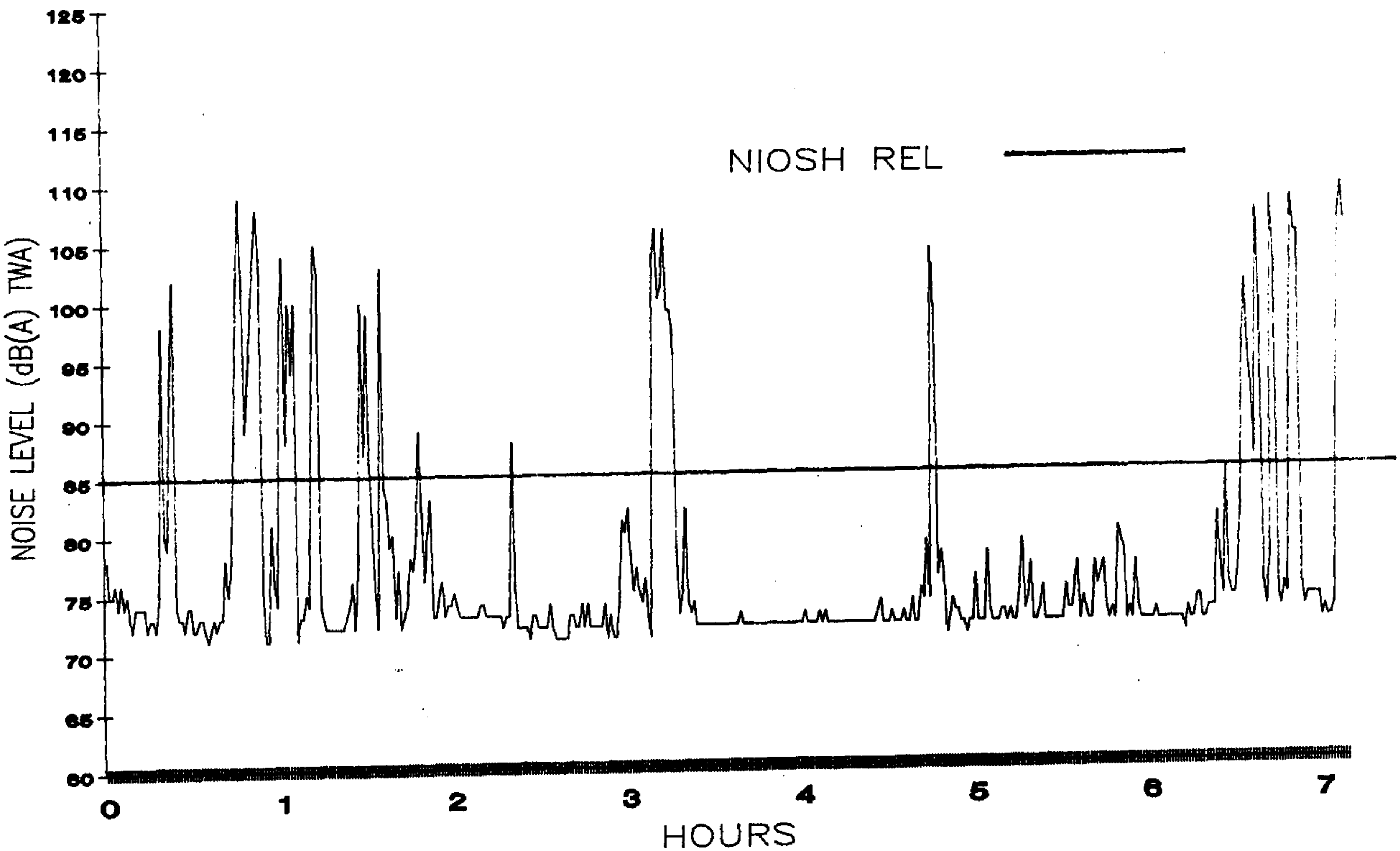


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Office Clerk

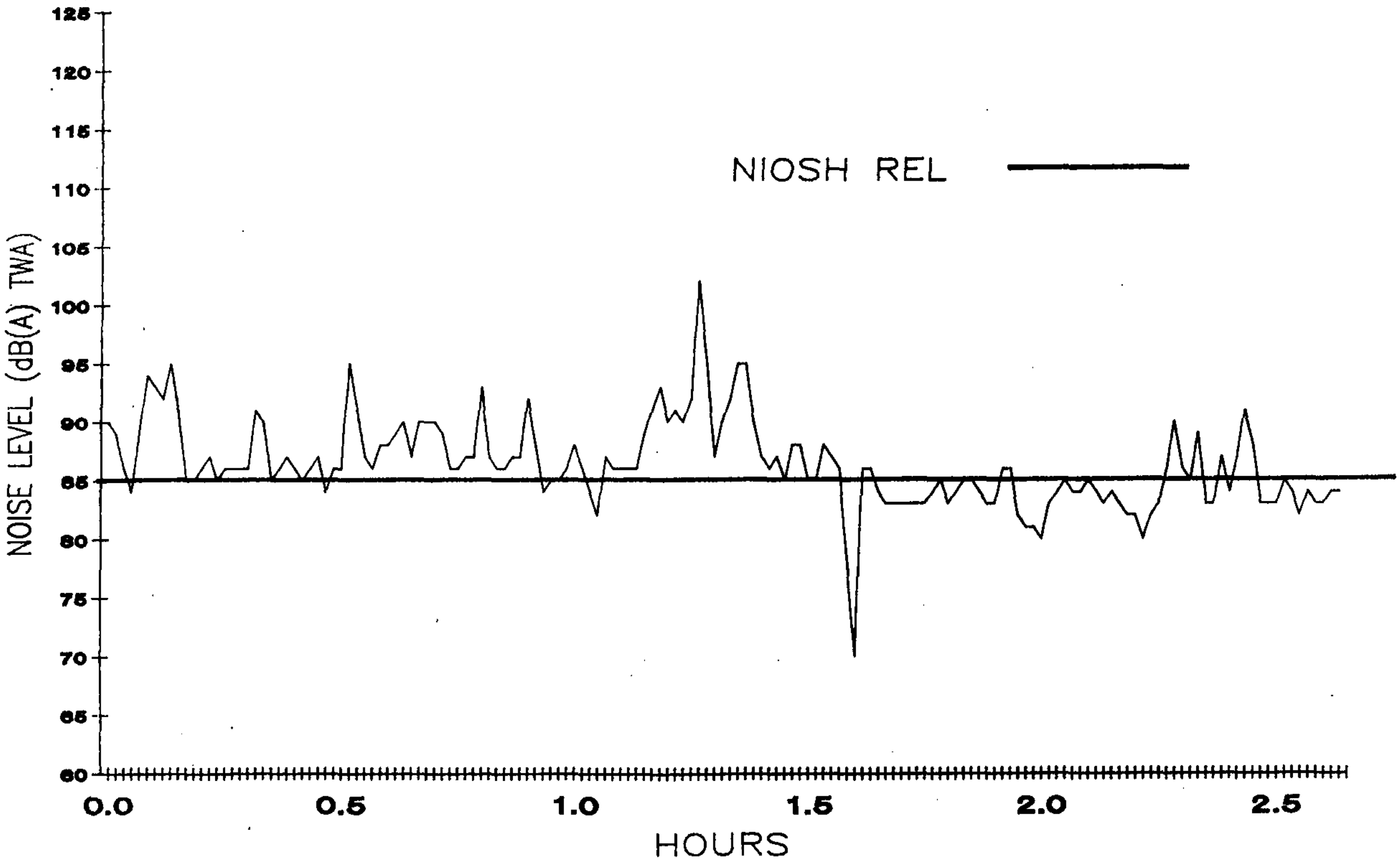


HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Tobacco Cutter



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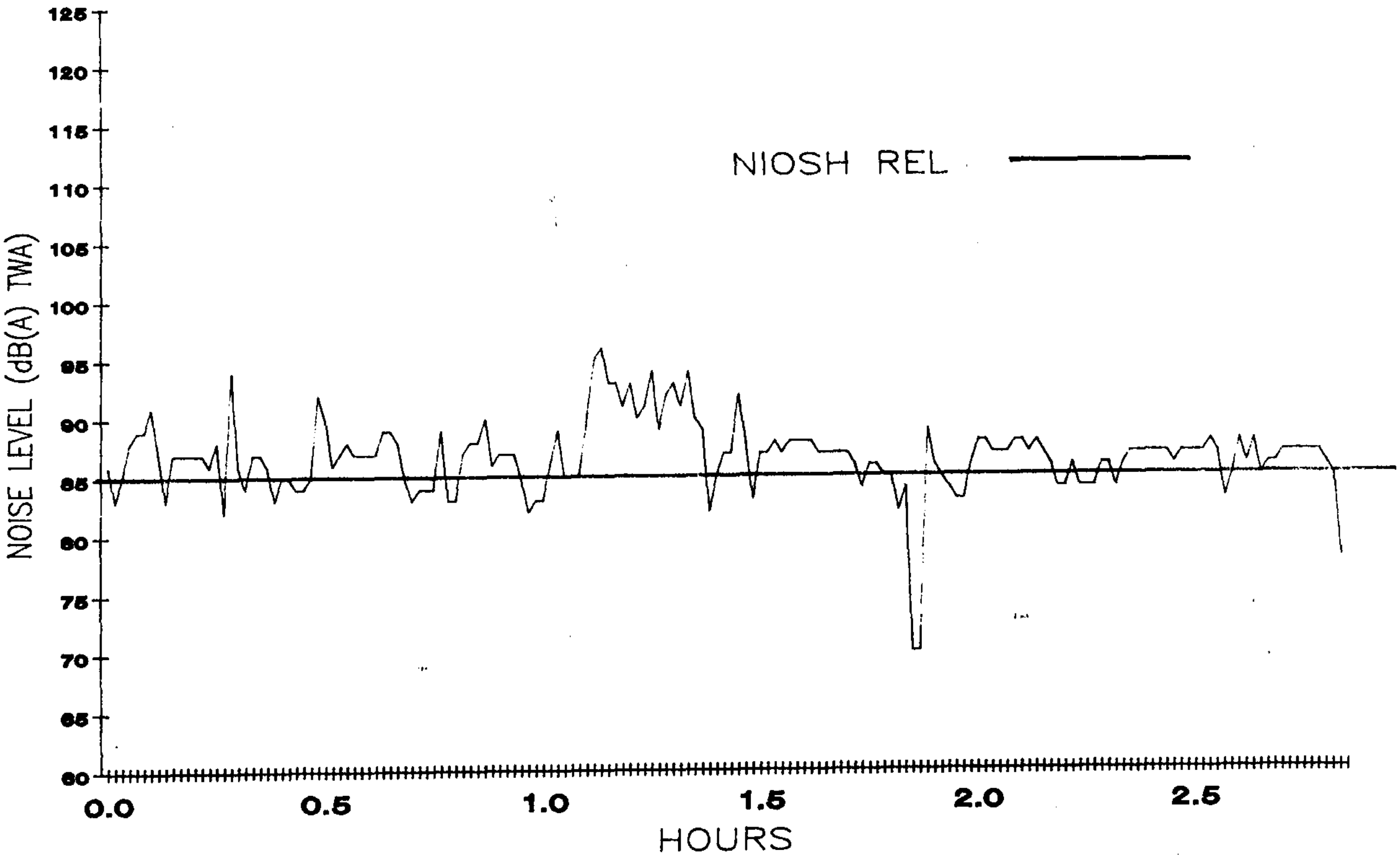
St. Lucia Noise Survey
N.Y. Daher Tobacco Co.
Tobacco Dryer

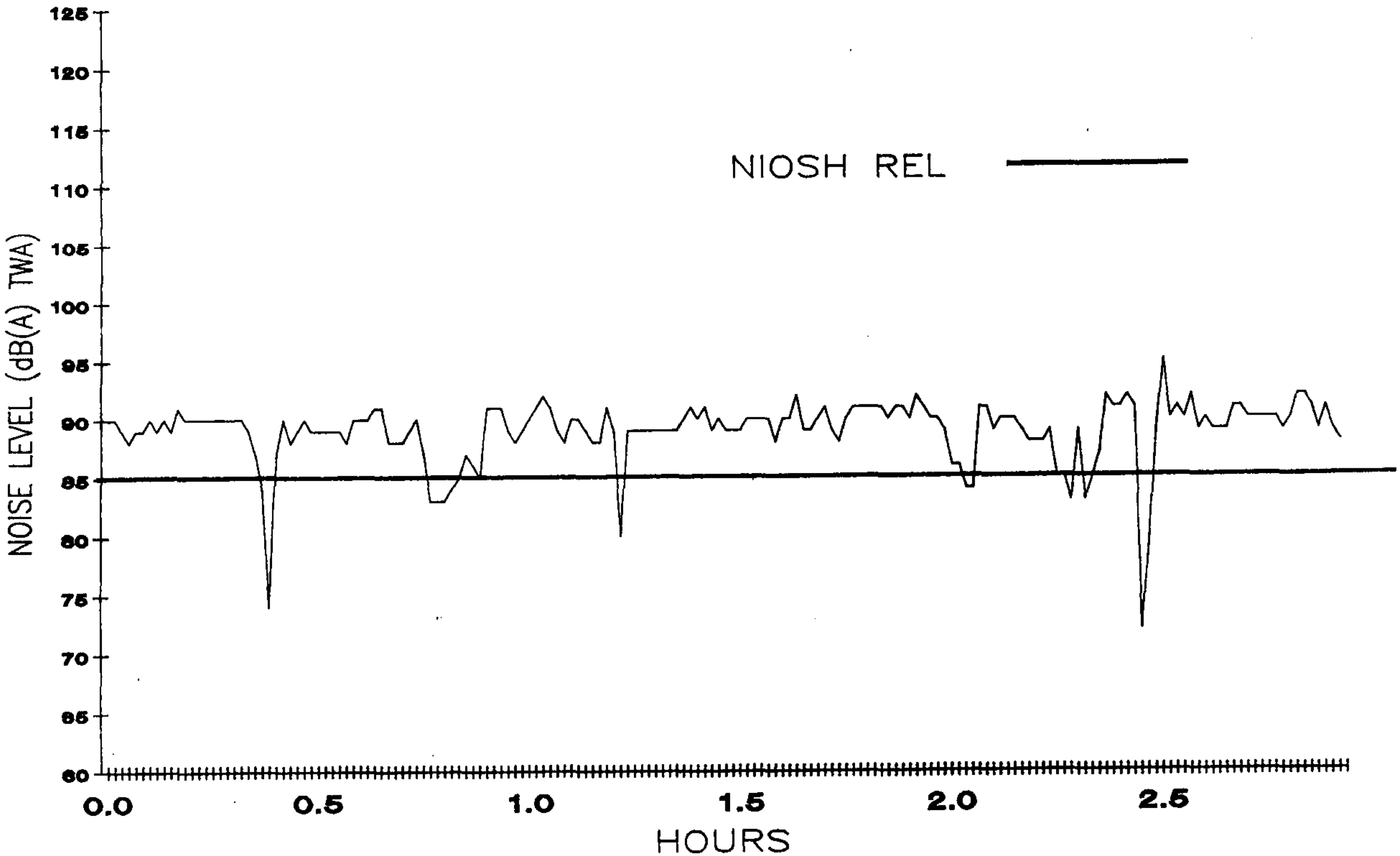


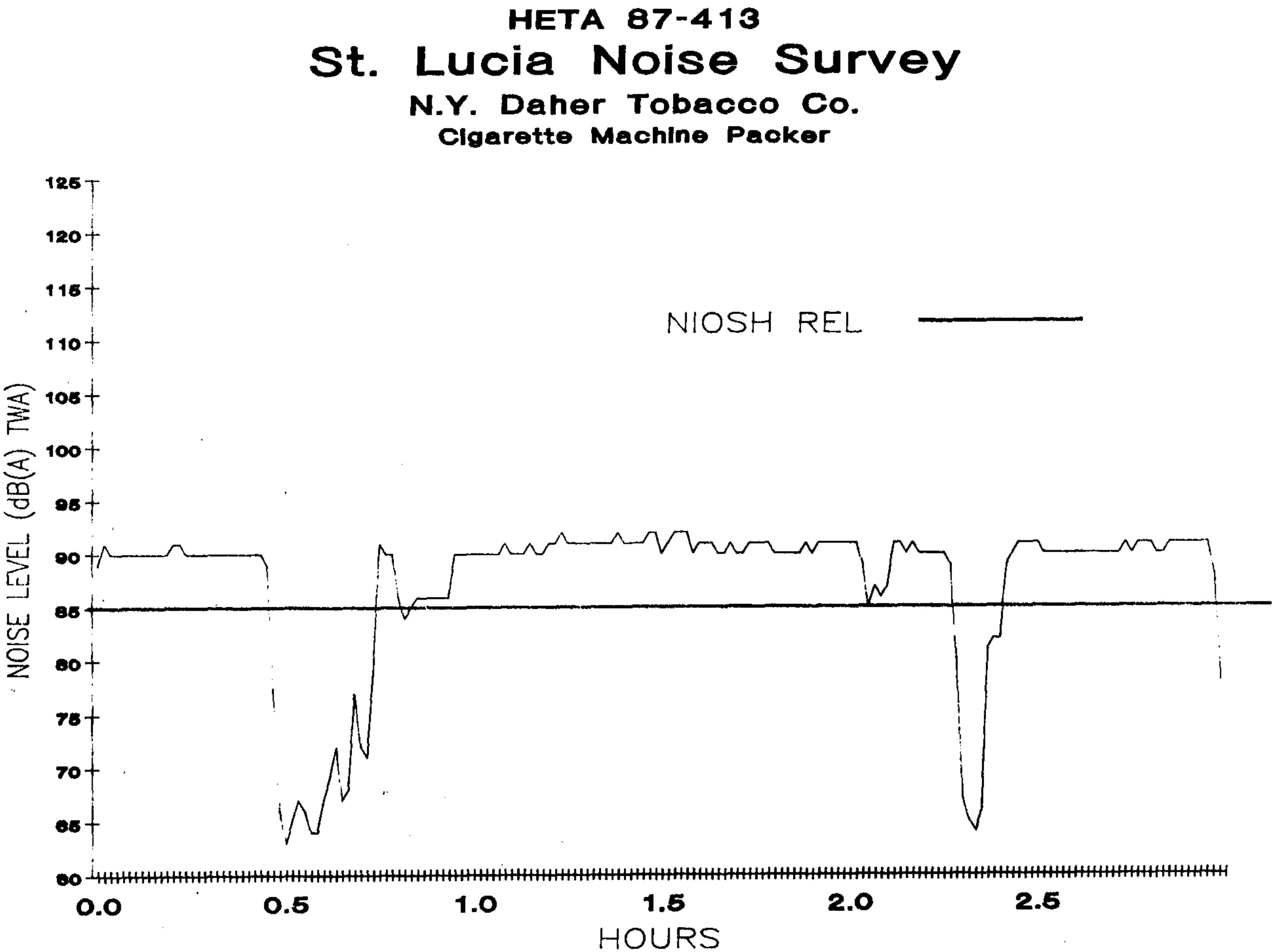
HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Machine Operator



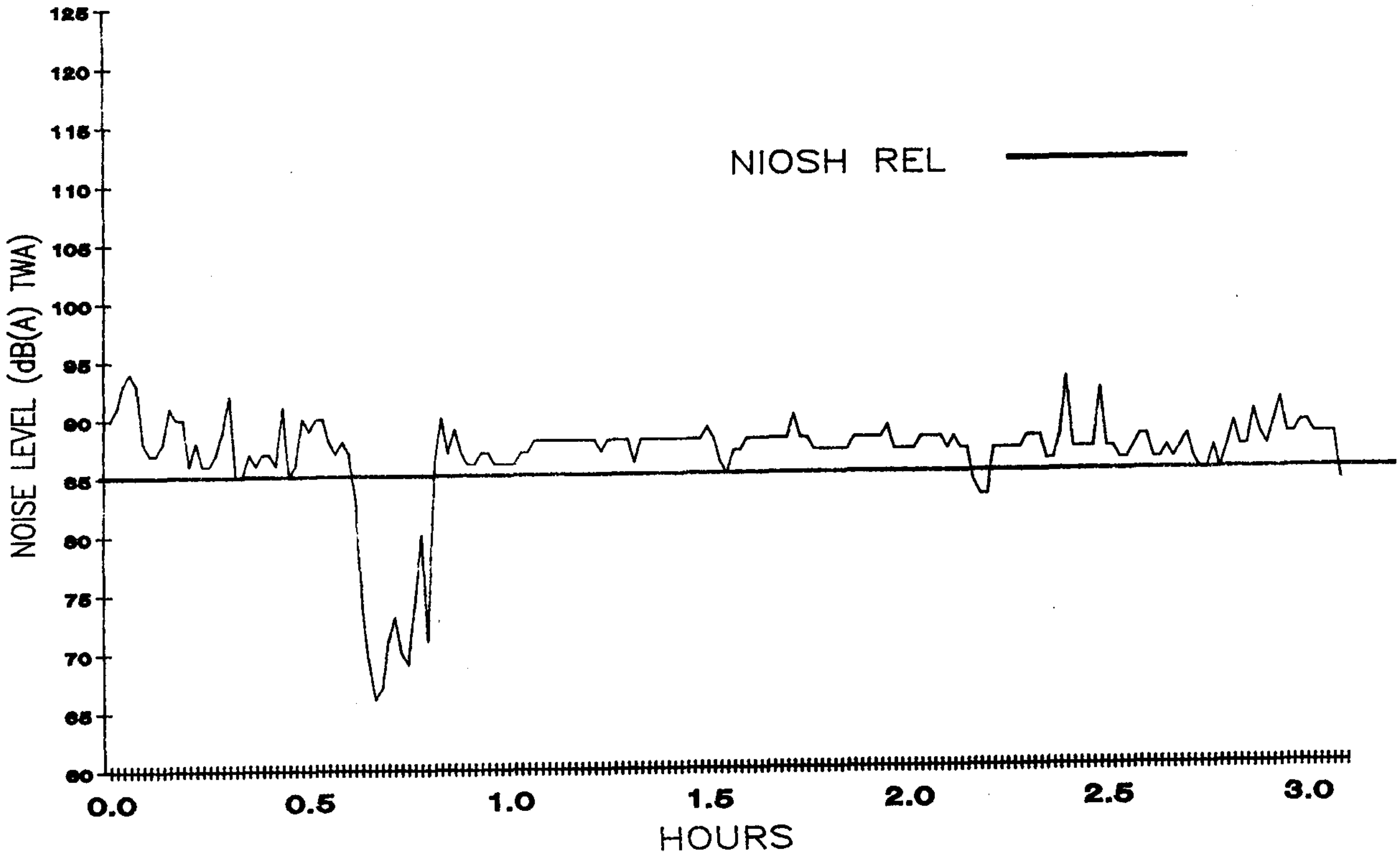

HETA 87-413
St. Lucia Noise Survey
N.Y. Daher Tobacco Co.
Cigarette Machine Packer
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0.0
0.5
1.0
1.5
2.0
2.5
HOURS

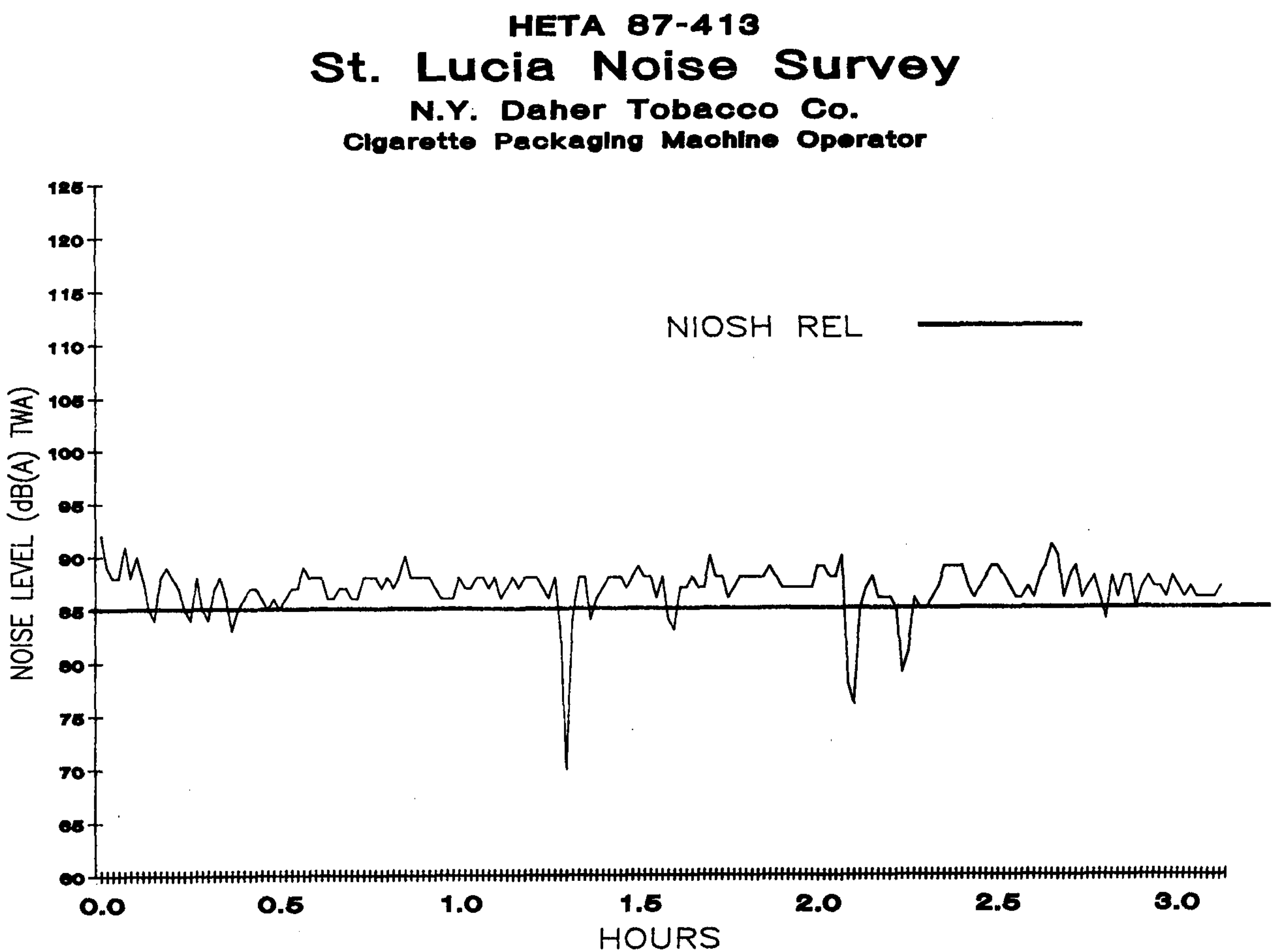
HETA 87-413

St. Lucia Noise Survey

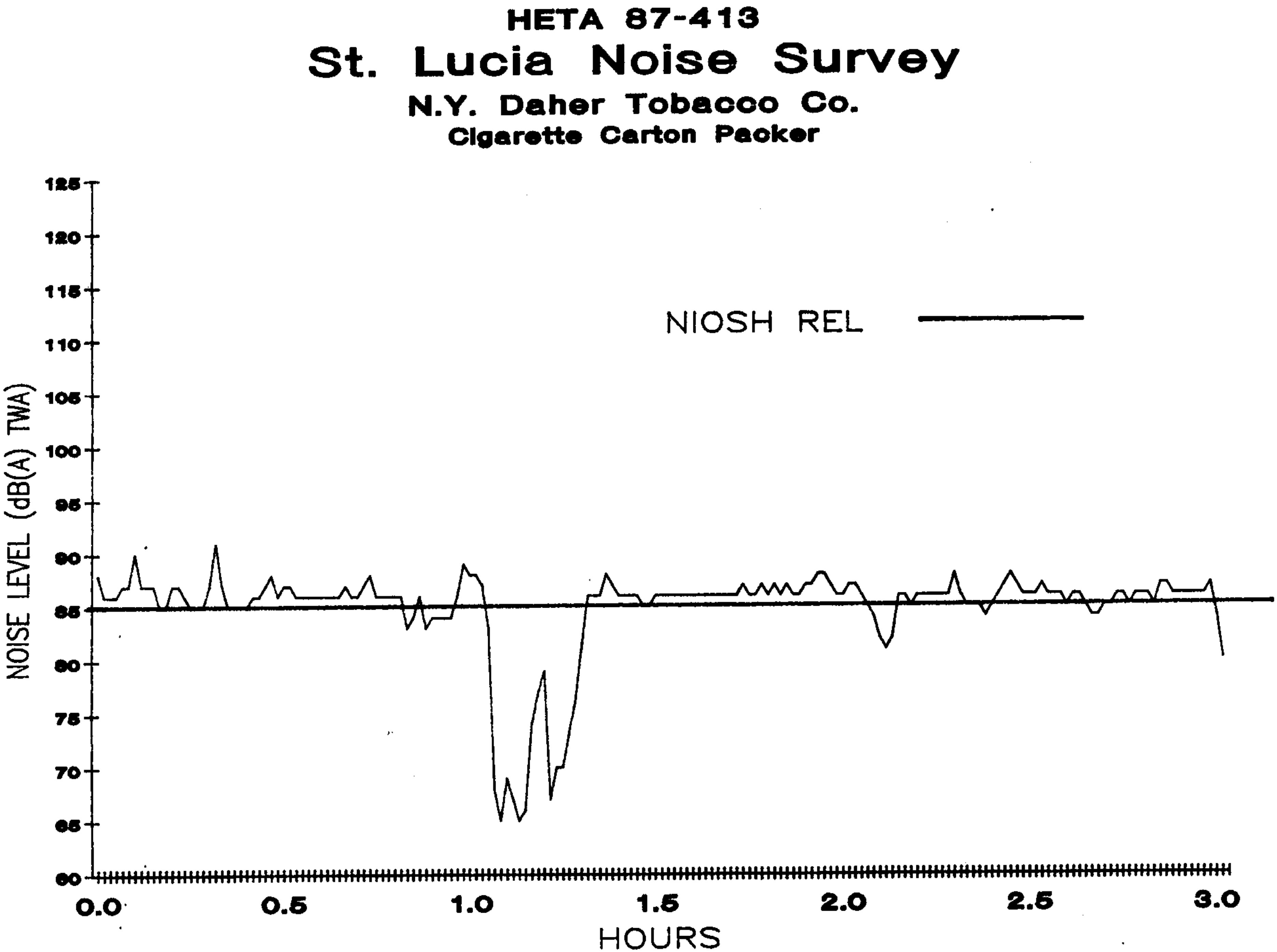
N.Y. Daher Tobacco Co.

Cigarette Packaging Machine Filler





HETA 87-413
St. Lucia Noise Survey
N.Y. Daher Tobacco Co.
Cigarette Packaging Machine Operator
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0
HOURS

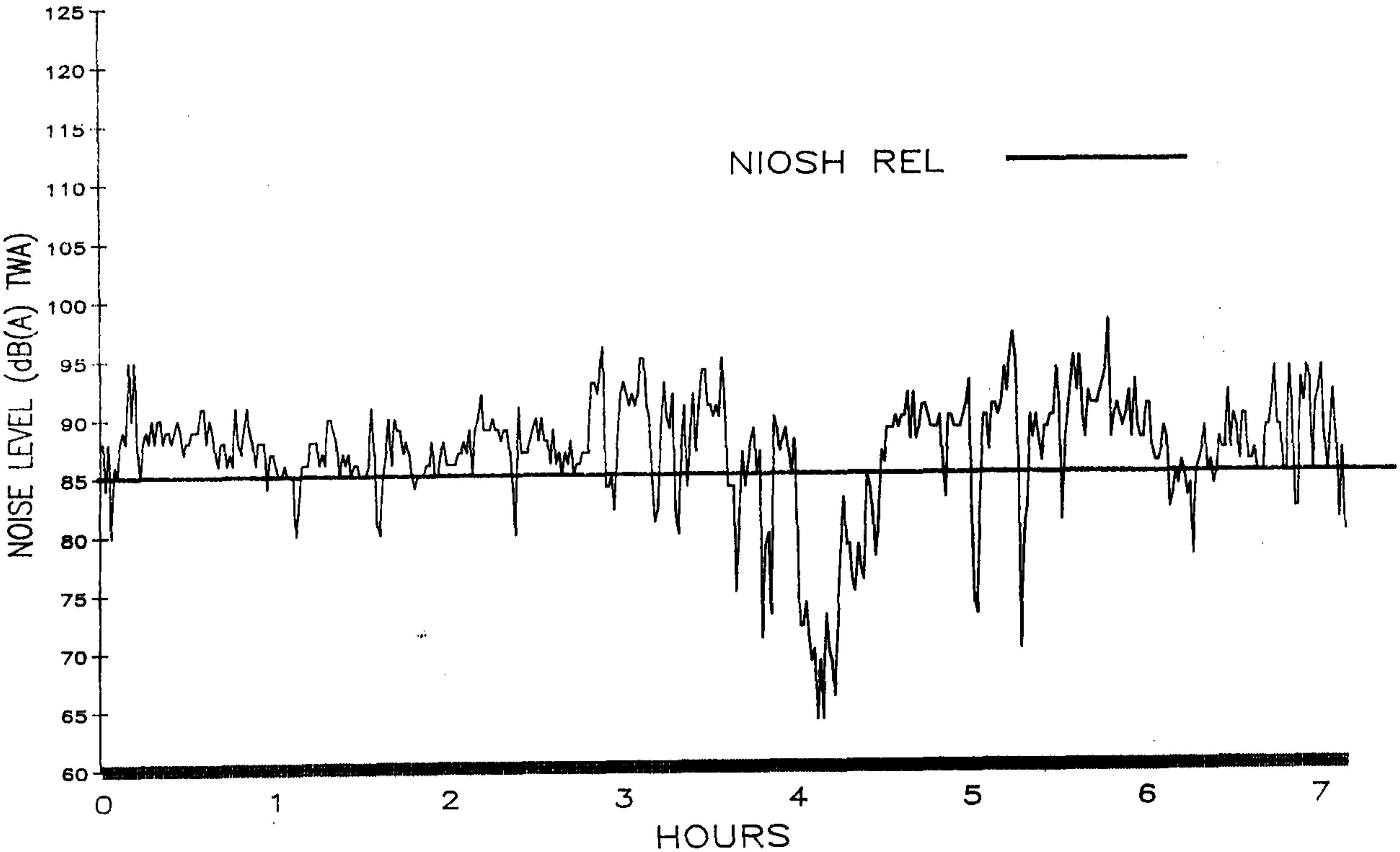

HETA 87-413
St. Lucia Noise Survey
N.Y. Daher Tobacco Co.
Cigarette Carton Packer
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0
HOURS

HETA 87-413

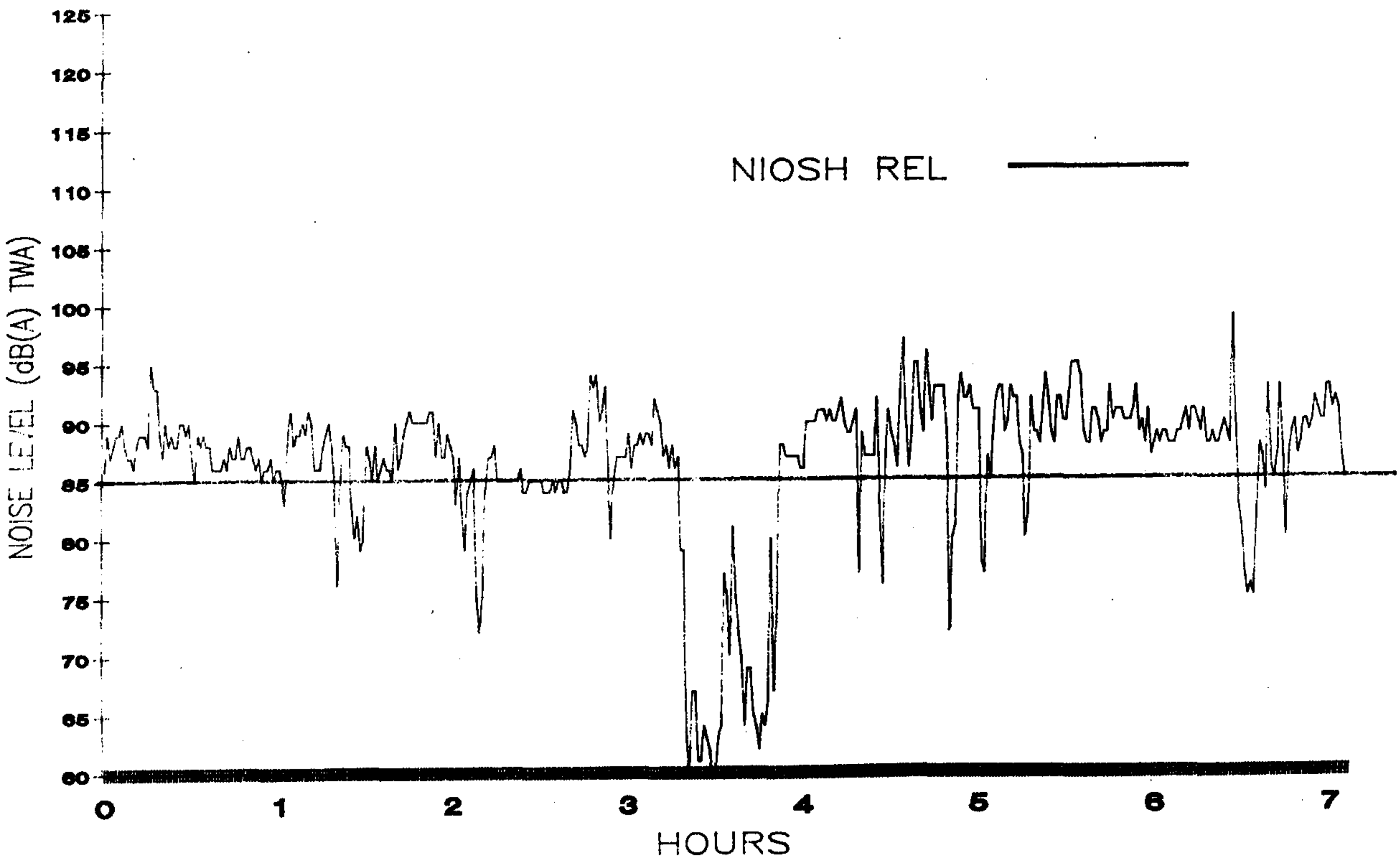
St. Lucia Noise Survey

Ramco Plastics

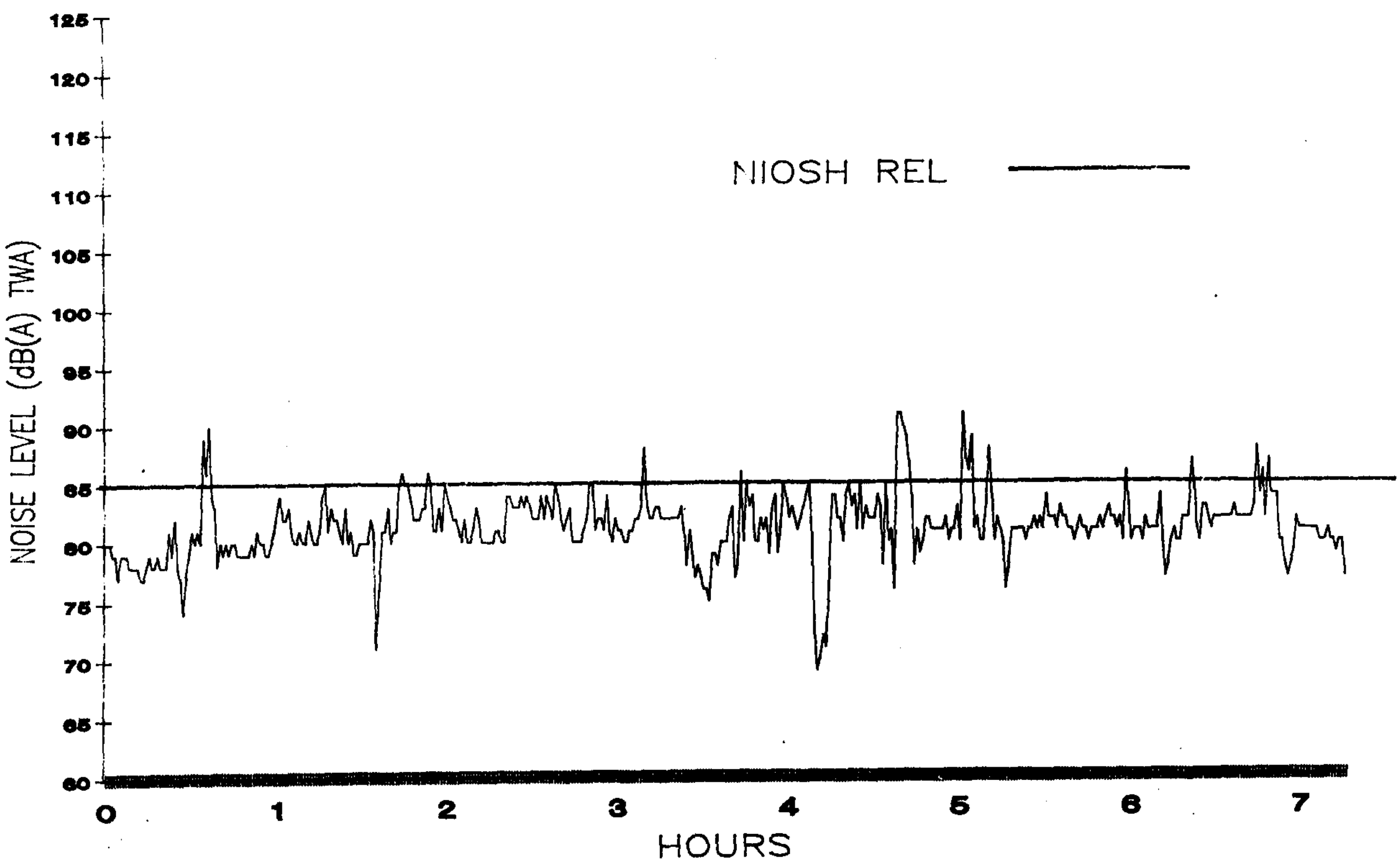
Plastic Film Machine Operator "A"



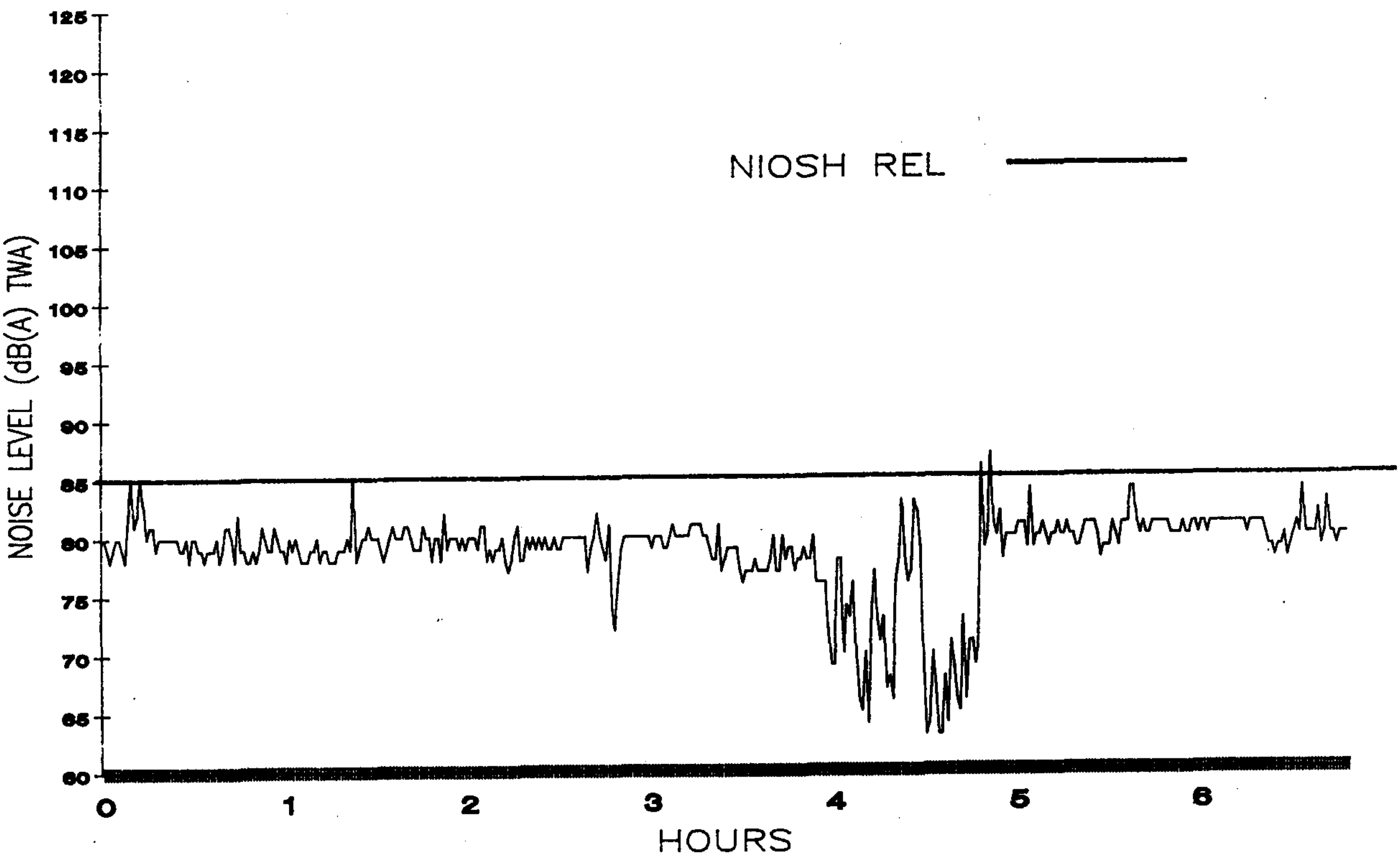
HETA 87-413
St. Lucia Noise Survey
Ramco Plastics
Plastic Film Machine Operator "B"



HETA 87-413
St. Lucia Noise Survey
Ramco Plastics
Bag Manufacturing Machine Operator "A"



HETA 87-413
St. Lucia Noise Survey
Ramco Plastics
Bag Manufacturing Machine Operator "B"

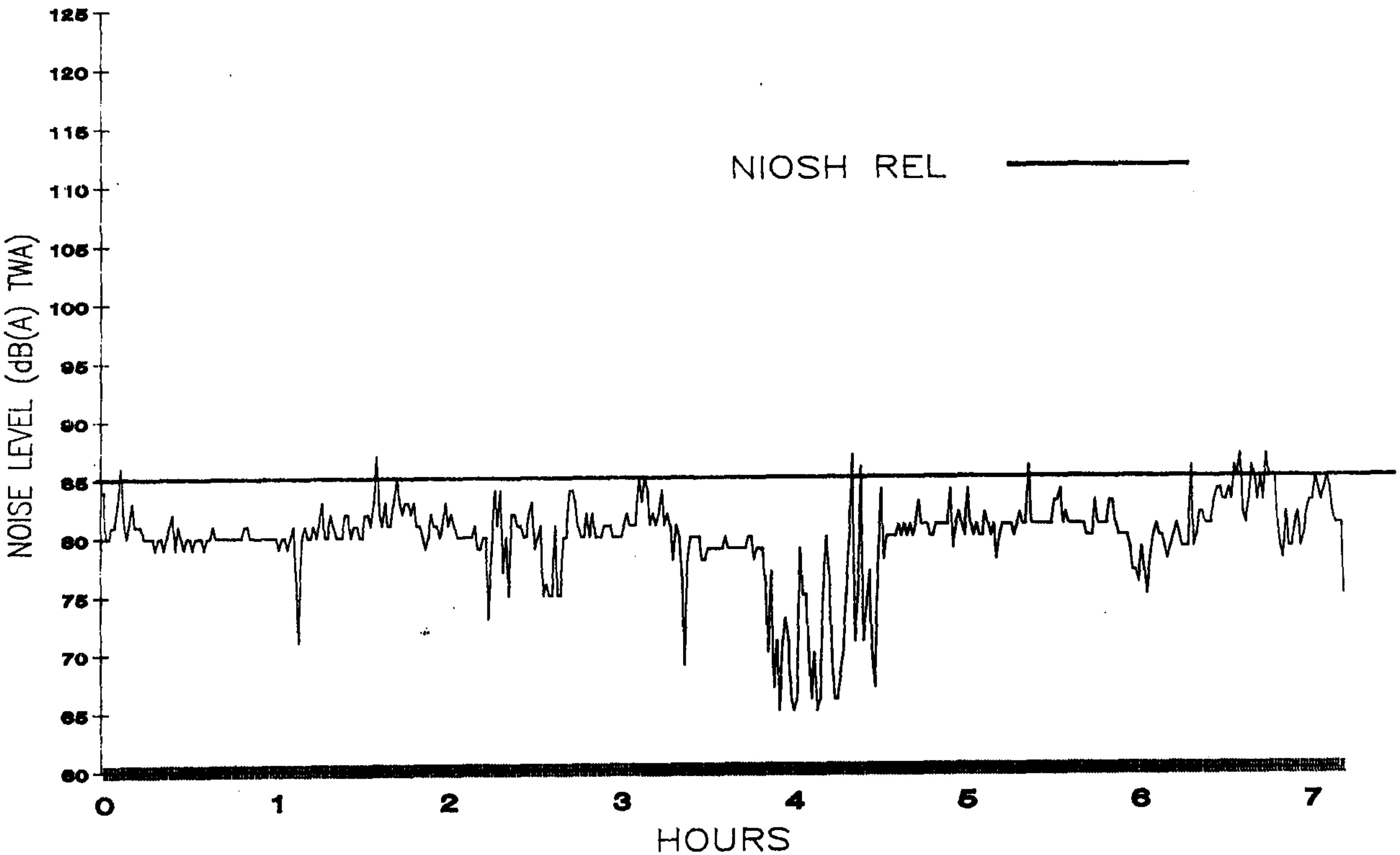


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Bag Manufacturing Machine Operator "C"

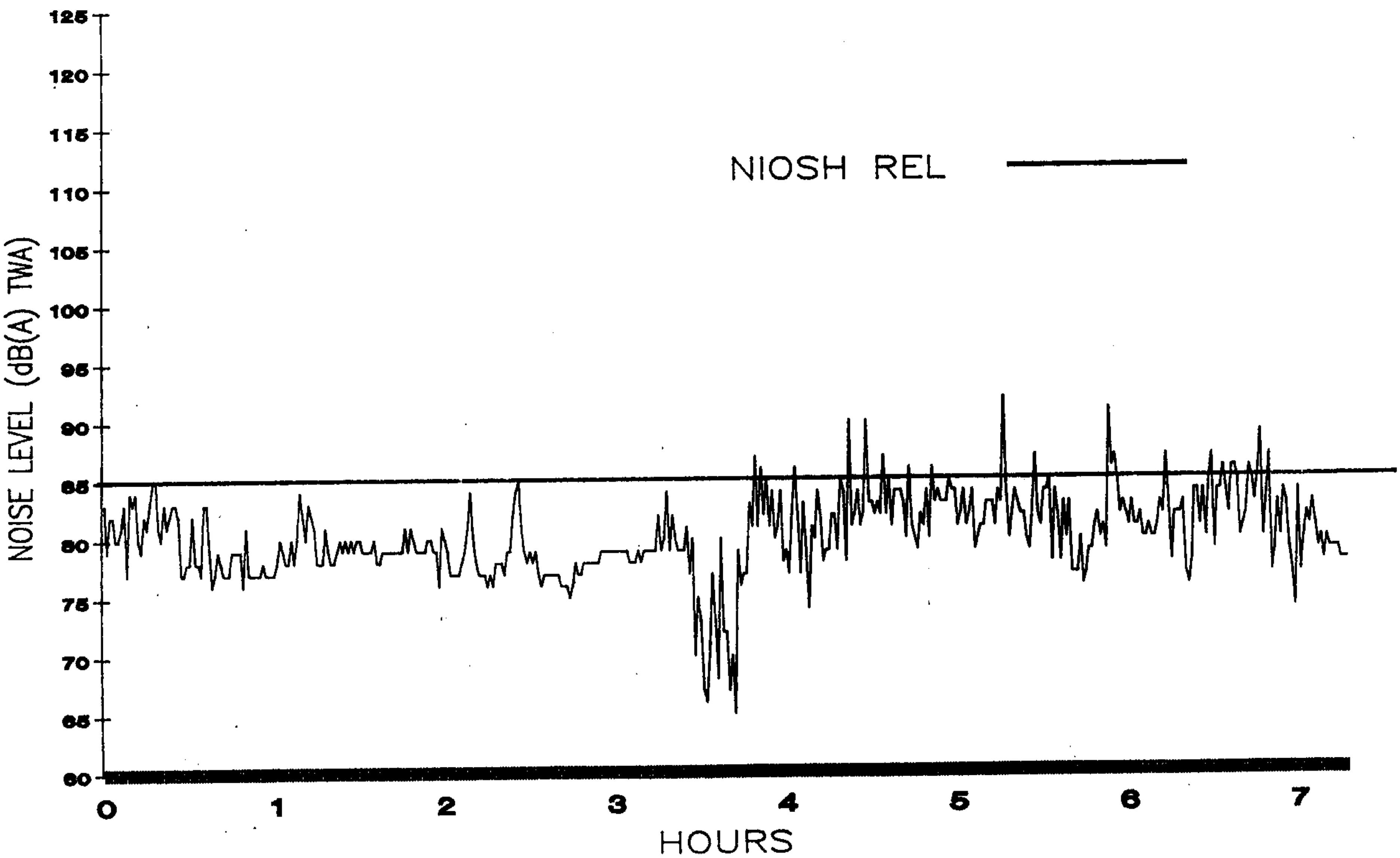


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Bag Cutting and Folding

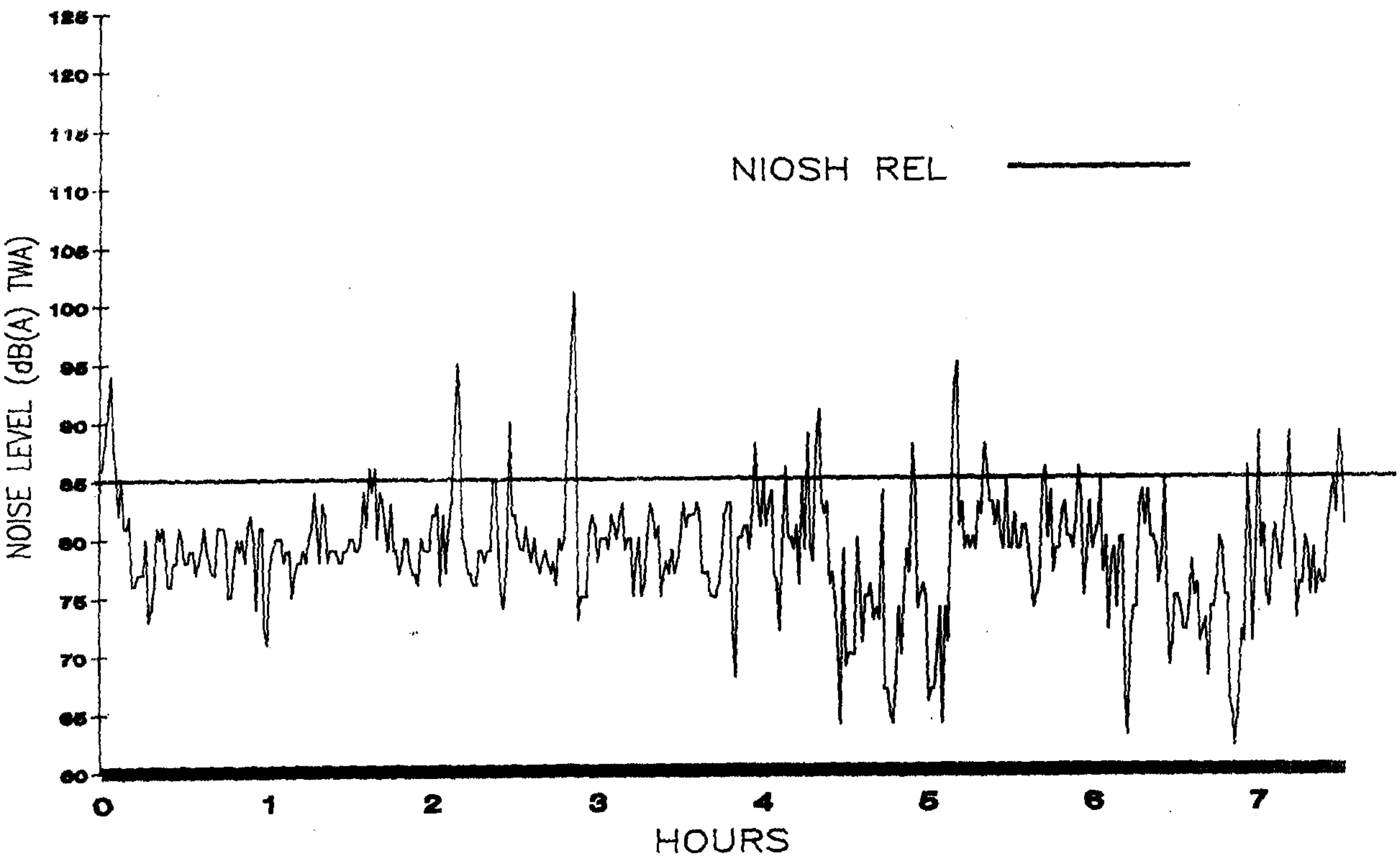


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Material Handler / Errands

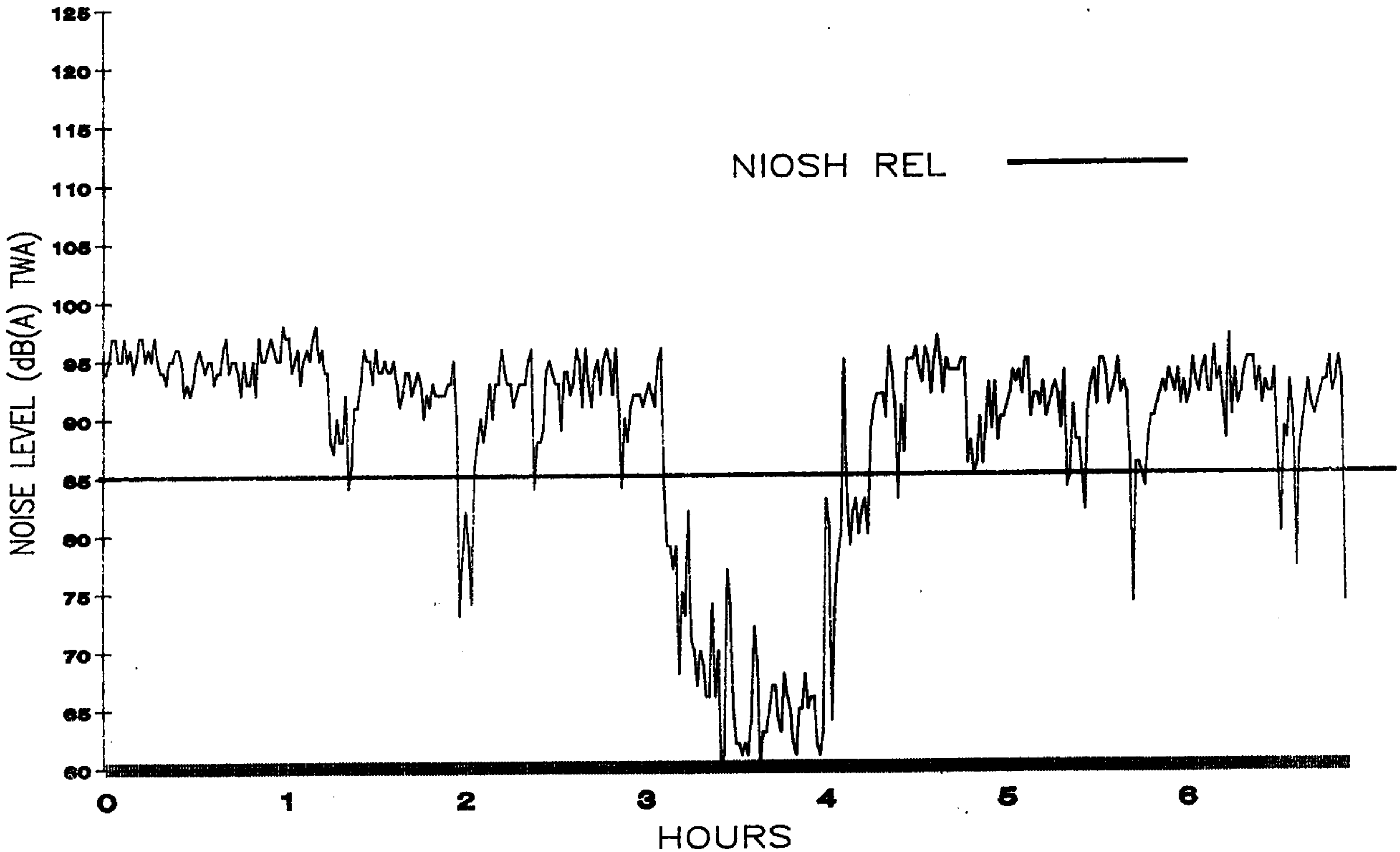


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Material Recycle Operator

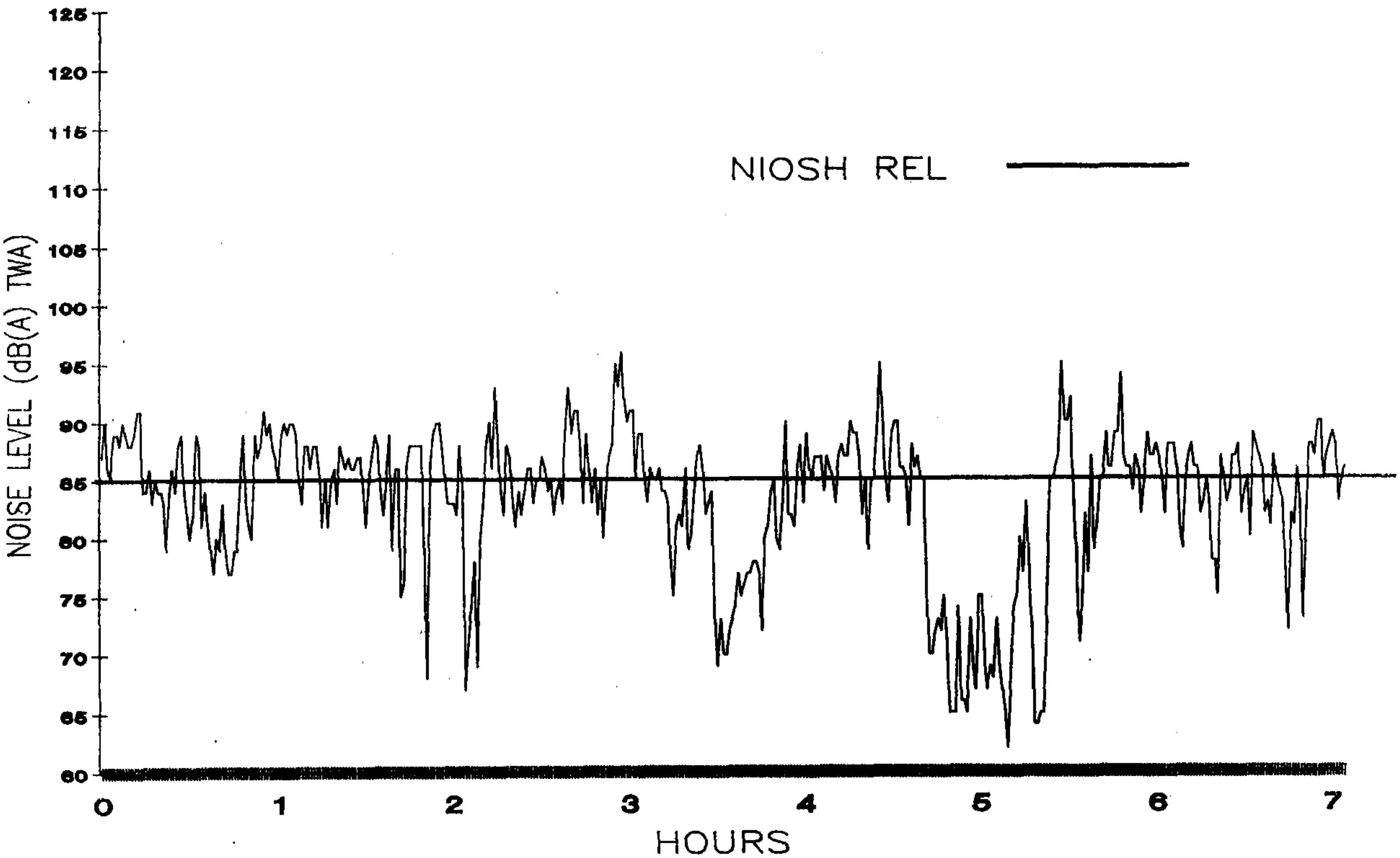


HETA 87-413

St. Lucia Noise Survey

DuBoulay's Bottling Co.

Bottle Washer

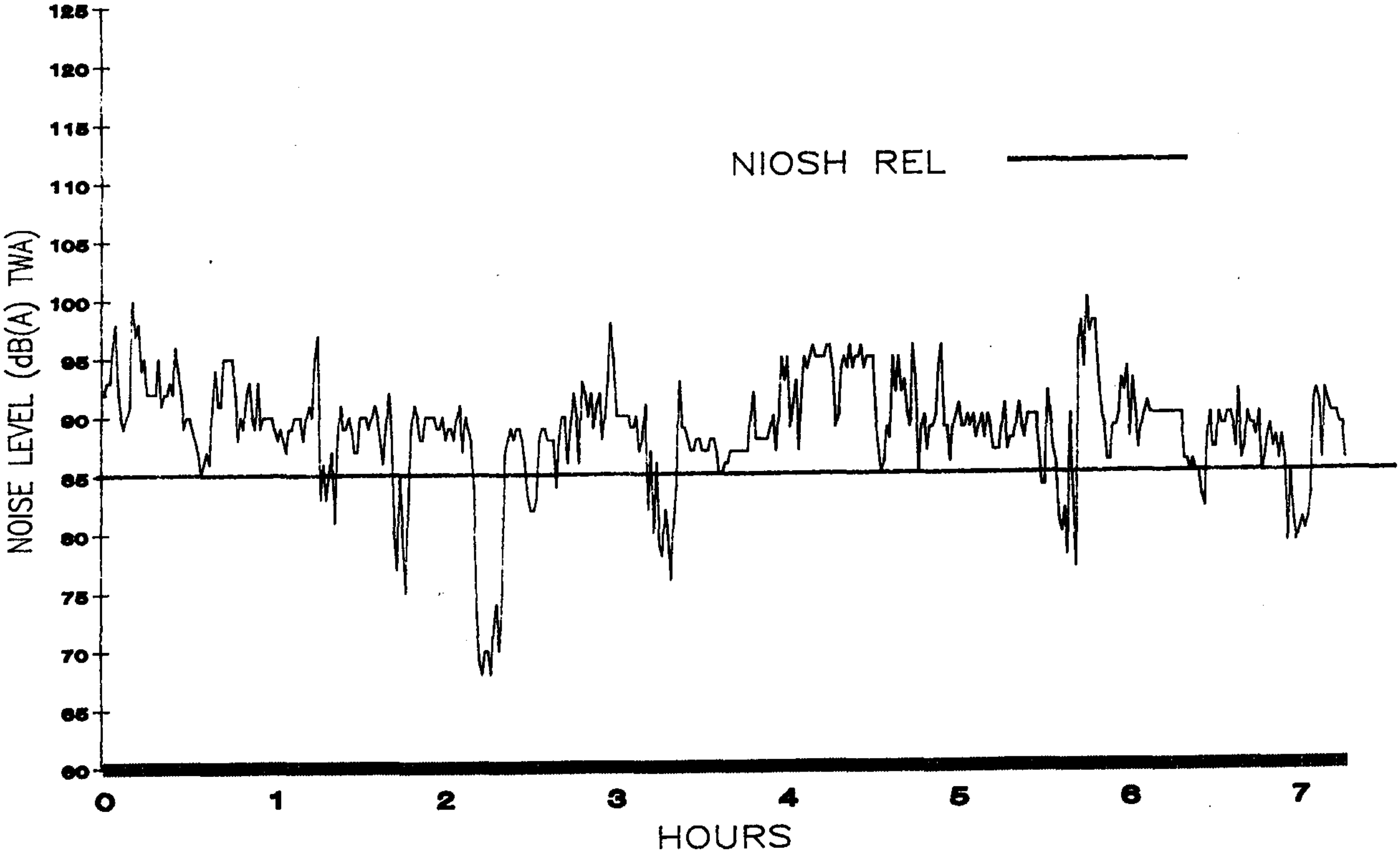


HETA 87-413

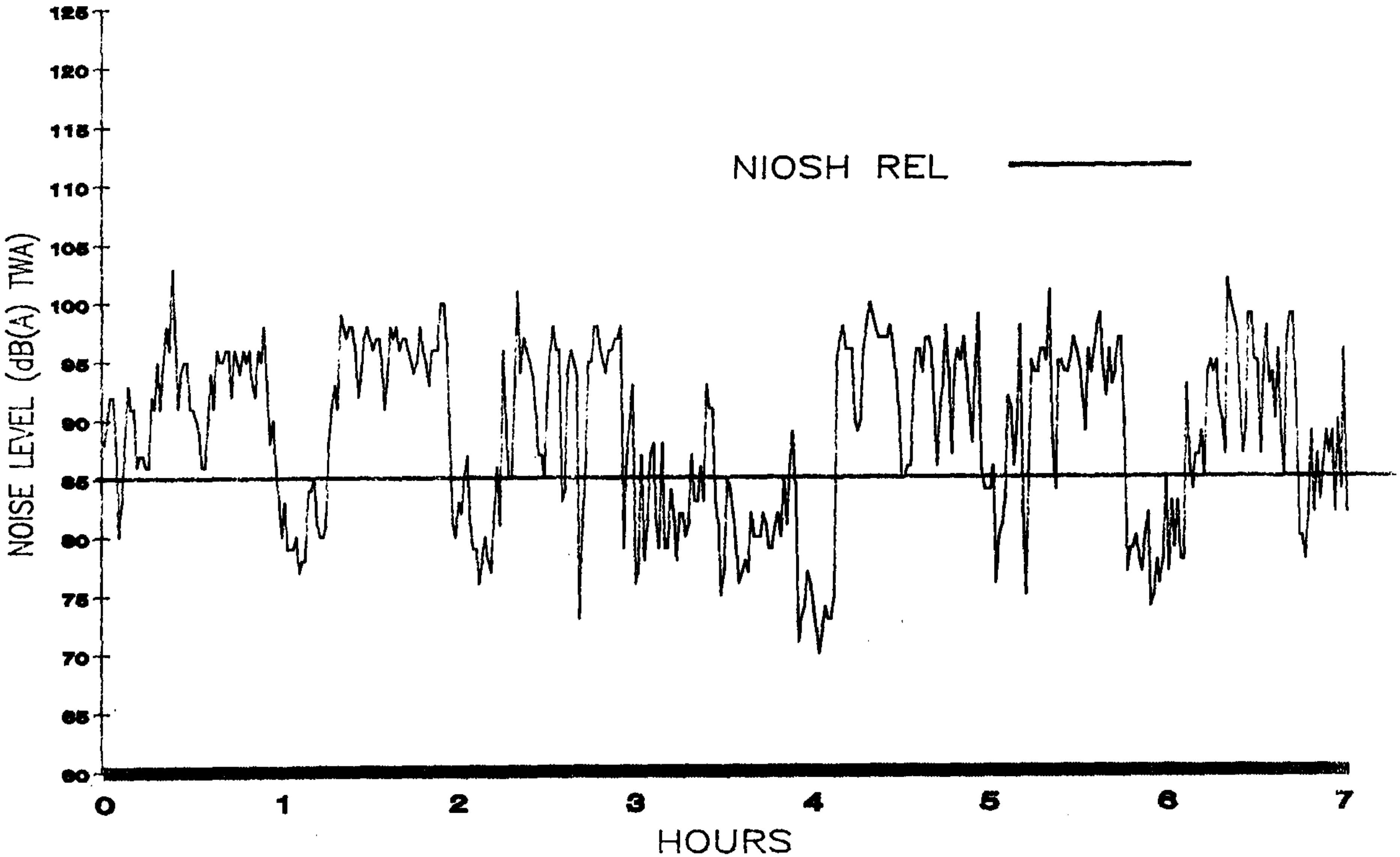
St. Lucia Noise Survey

DuBoulay's Bottling Co.

Bottling Room - Empty Bottle Inspector



HETA 87-413
St. Lucia Noise Survey
DuBoulay's Bottling Co.
Bottling Room - Filled Bottle Inspector

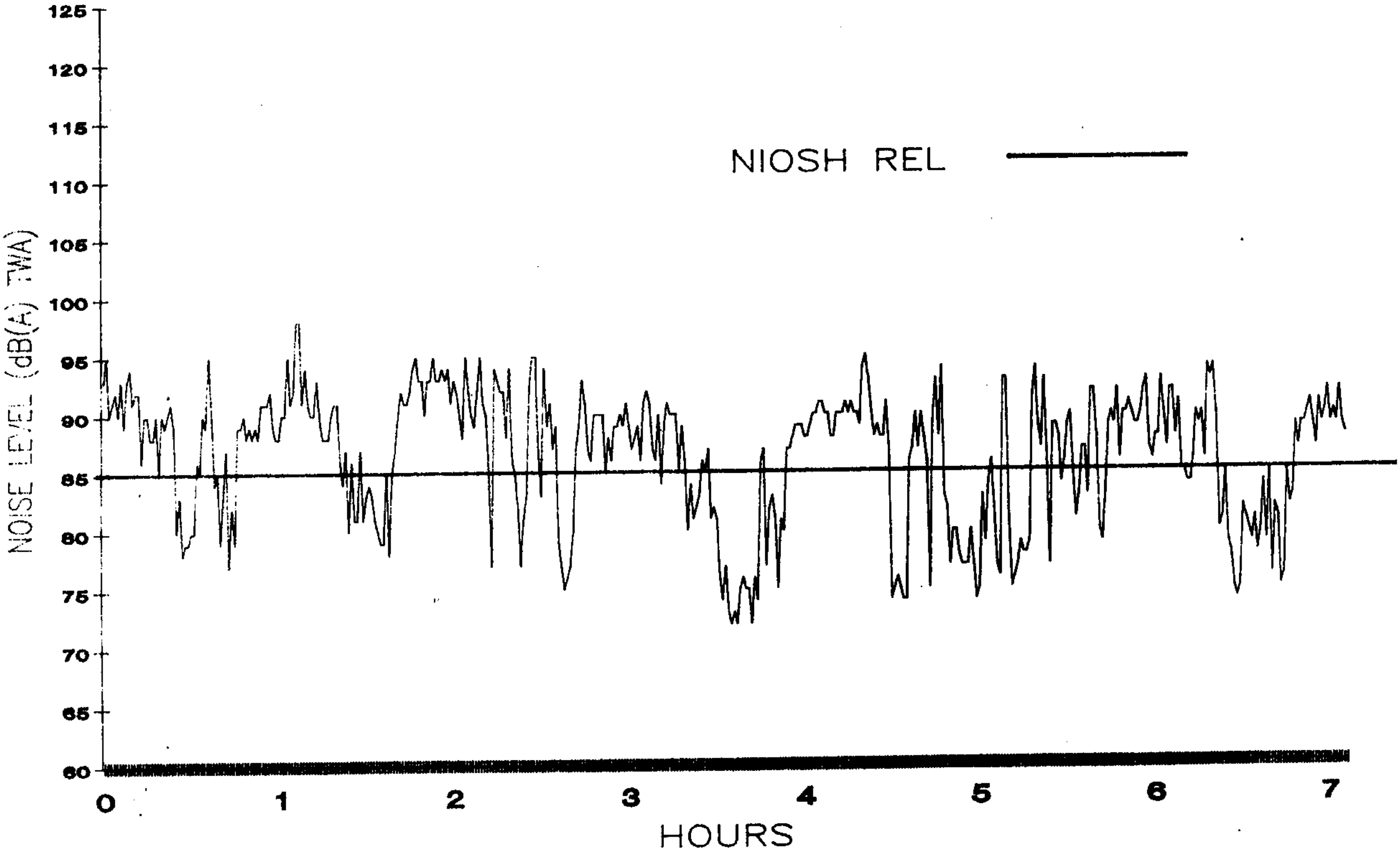


HETA 87-413

St. Lucia Noise Survey

DuBoulay's Bottling Co.

Warehouse - Case Packer

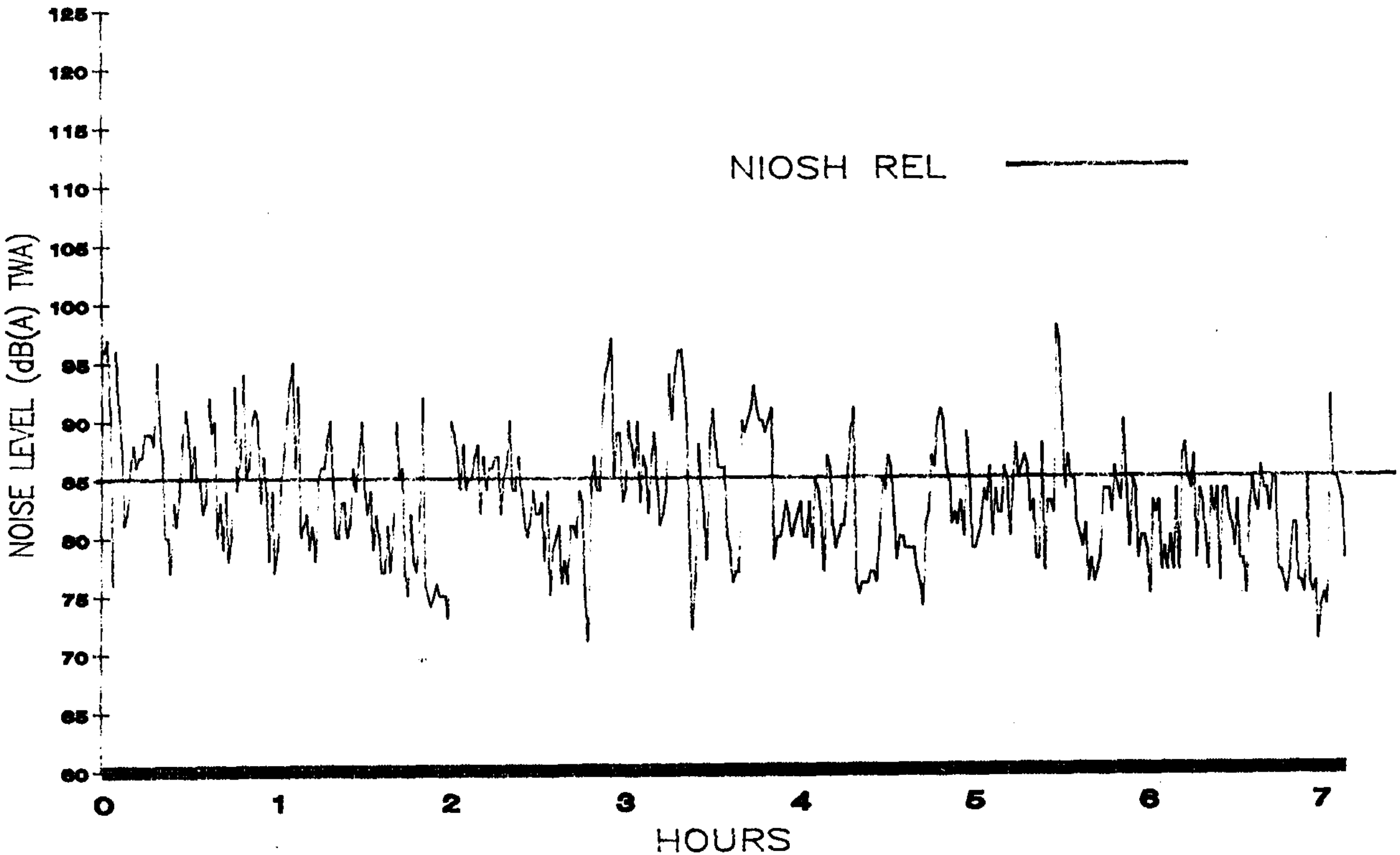


HETA 87-413

St. Lucia Noise Survey

DuBoulay's Bottling Co.

Supervisor

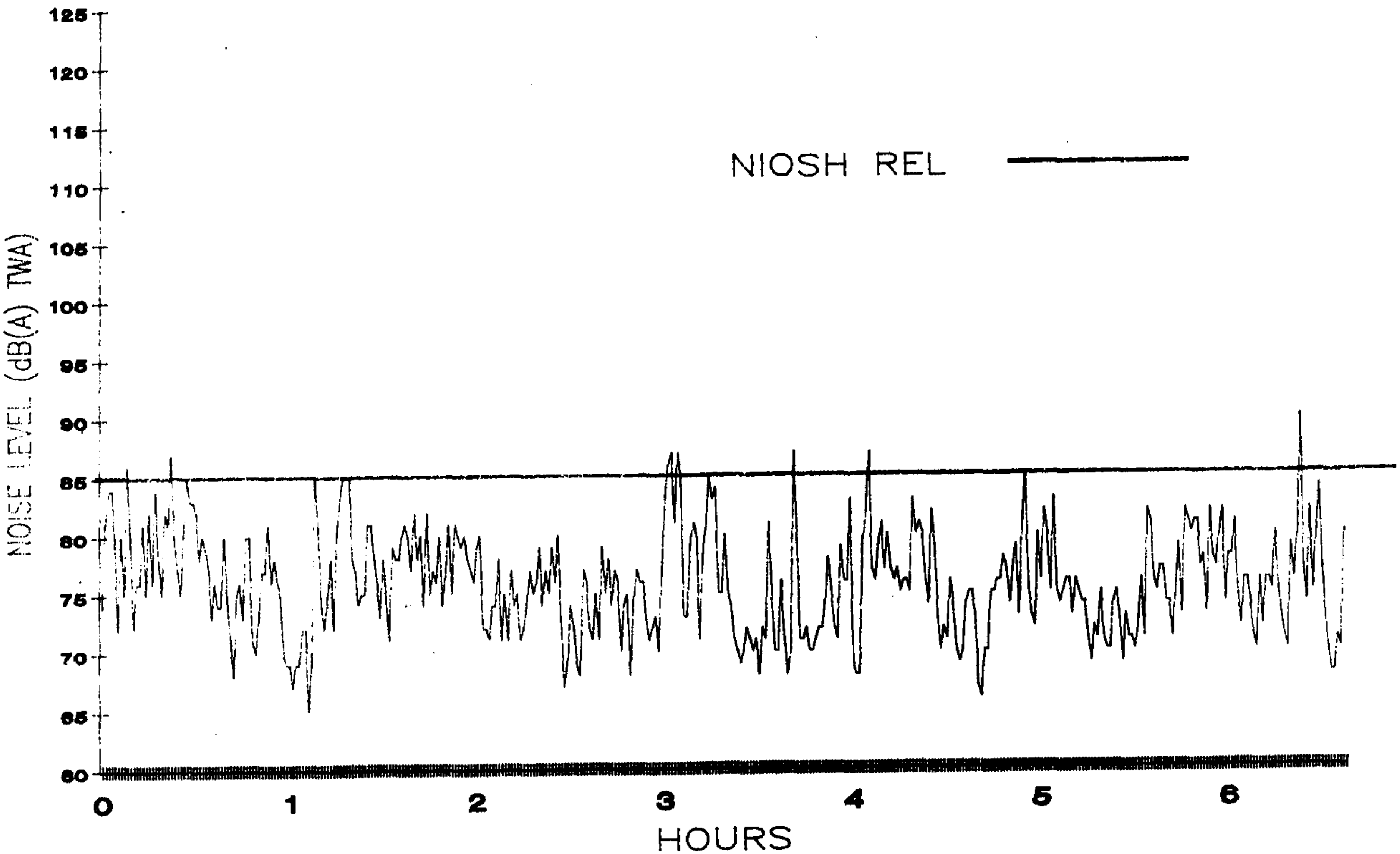


HETA 87-413

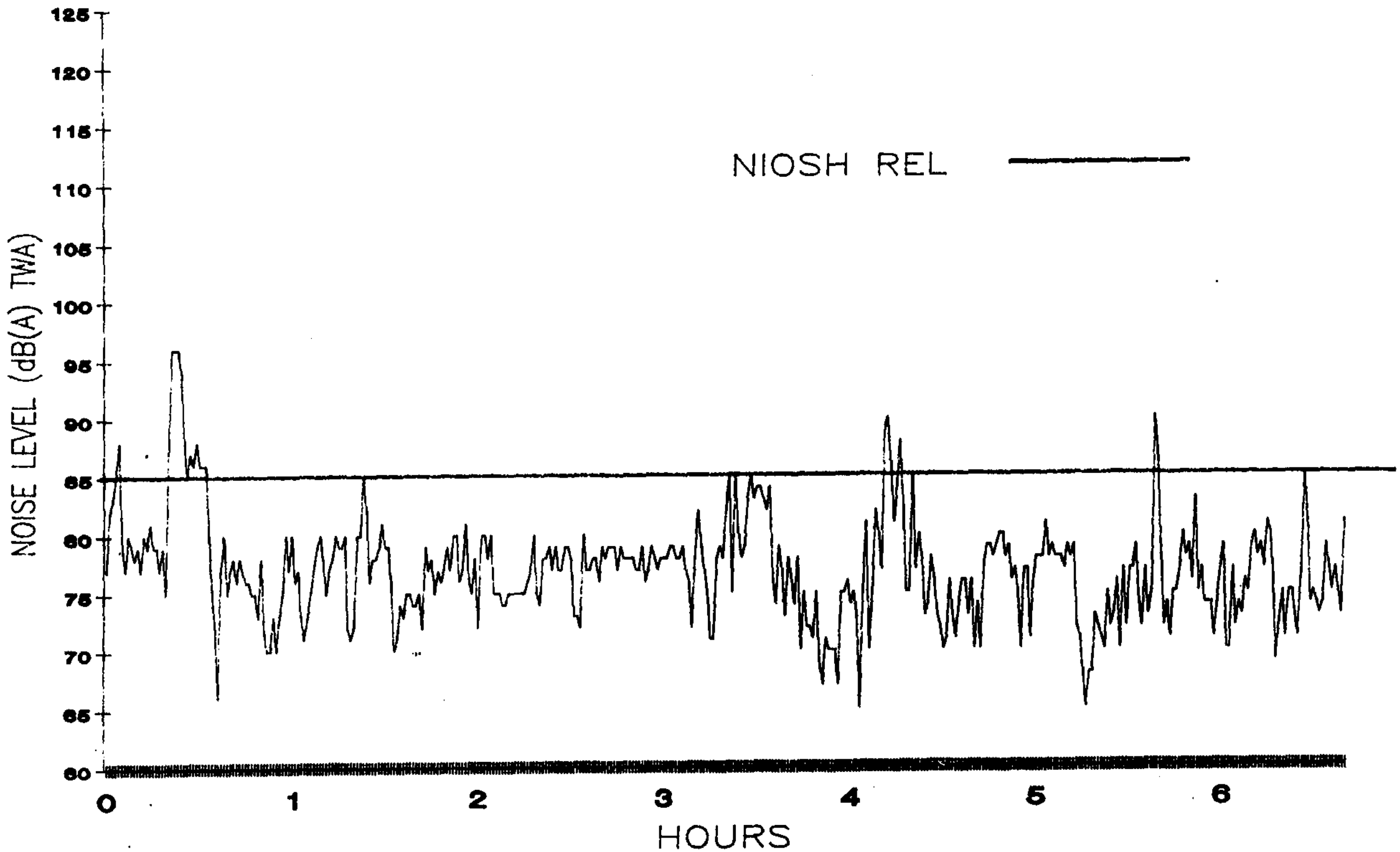
St. Lucia Noise Survey

Government Printery

Manual Type Setter



HETA 87-413
St. Lucia Noise Survey
Government Printery
Monotype Setter

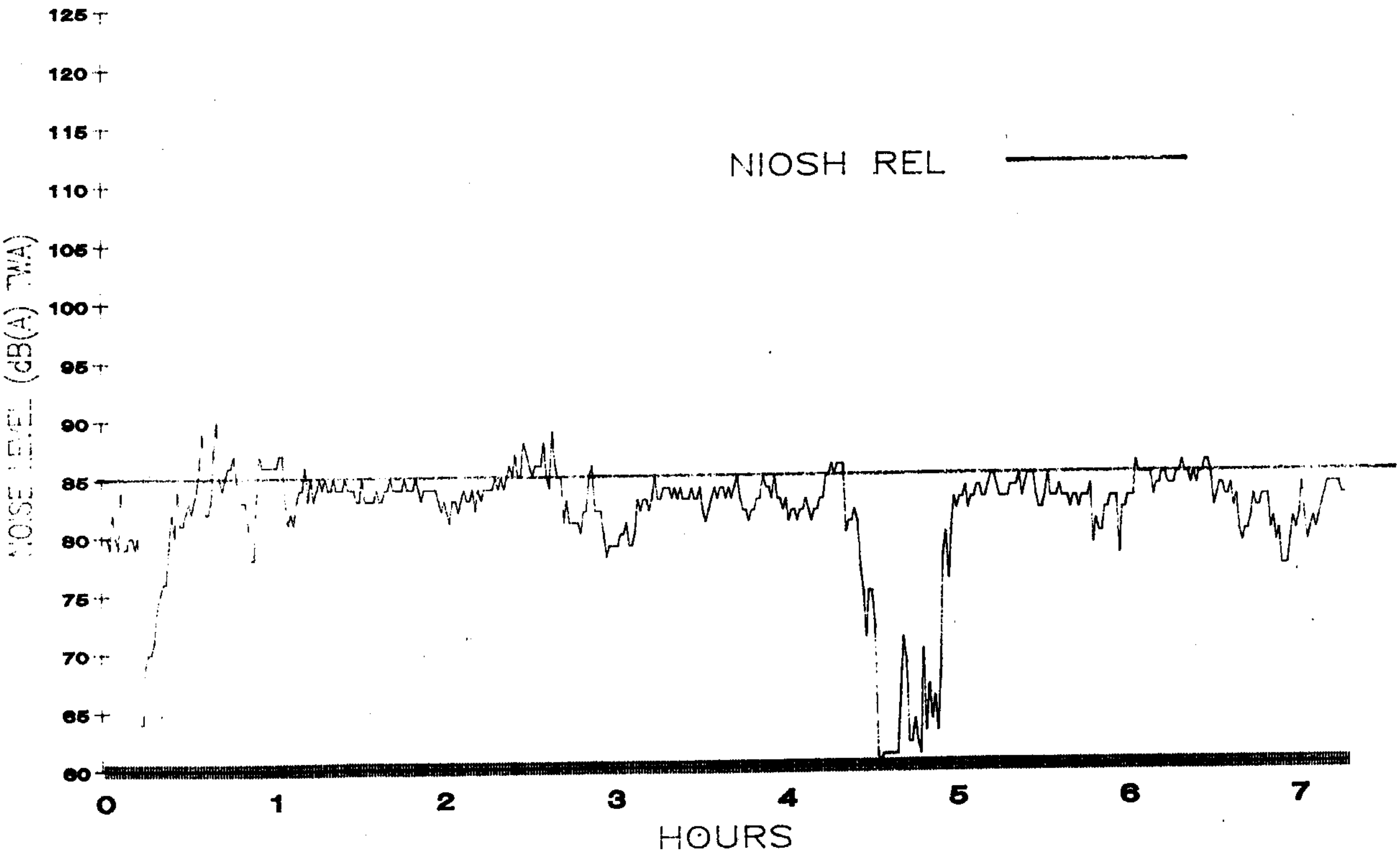


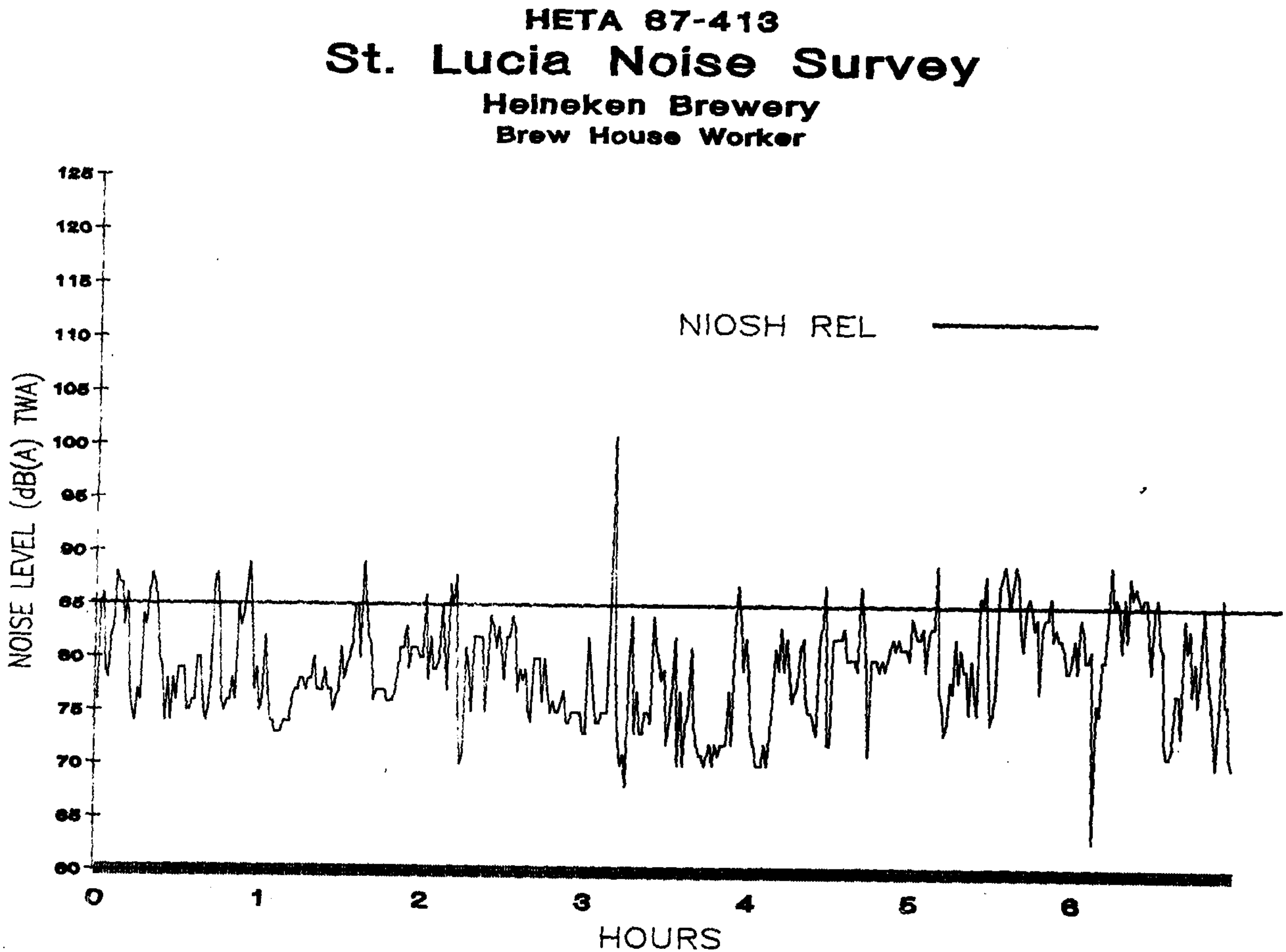
HETA 87-413

St. Lucia Noise Survey

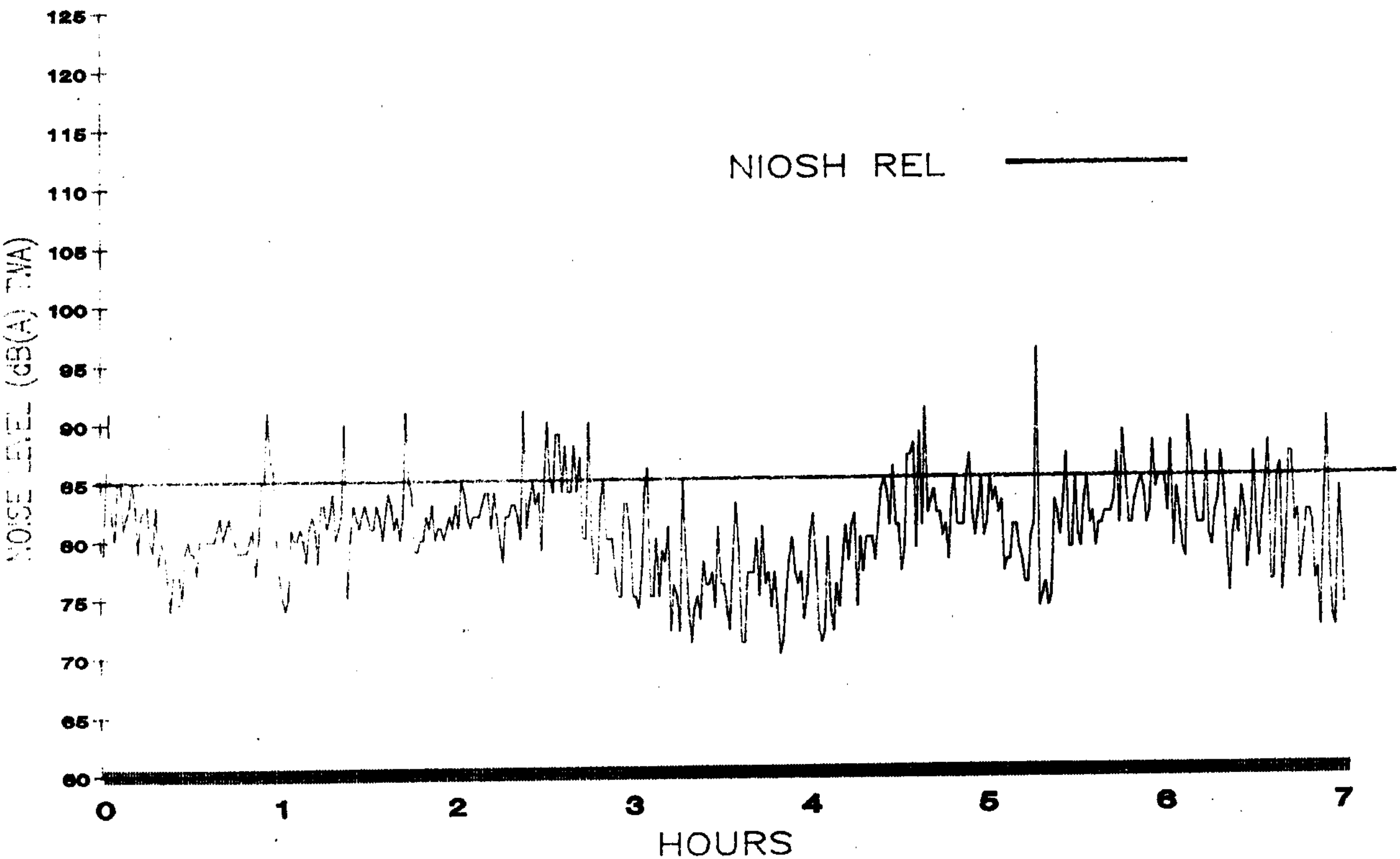
Tolyn Paper Company

Napkin Folding Machine




HETA 87-413
St. Lucia Noise Survey
Heineken Brewery
Brew House Worker
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
HOURS

HETA 87-413
St. Lucia Noise Survey
Heineken Brewery
Brew House - Cellar Worker

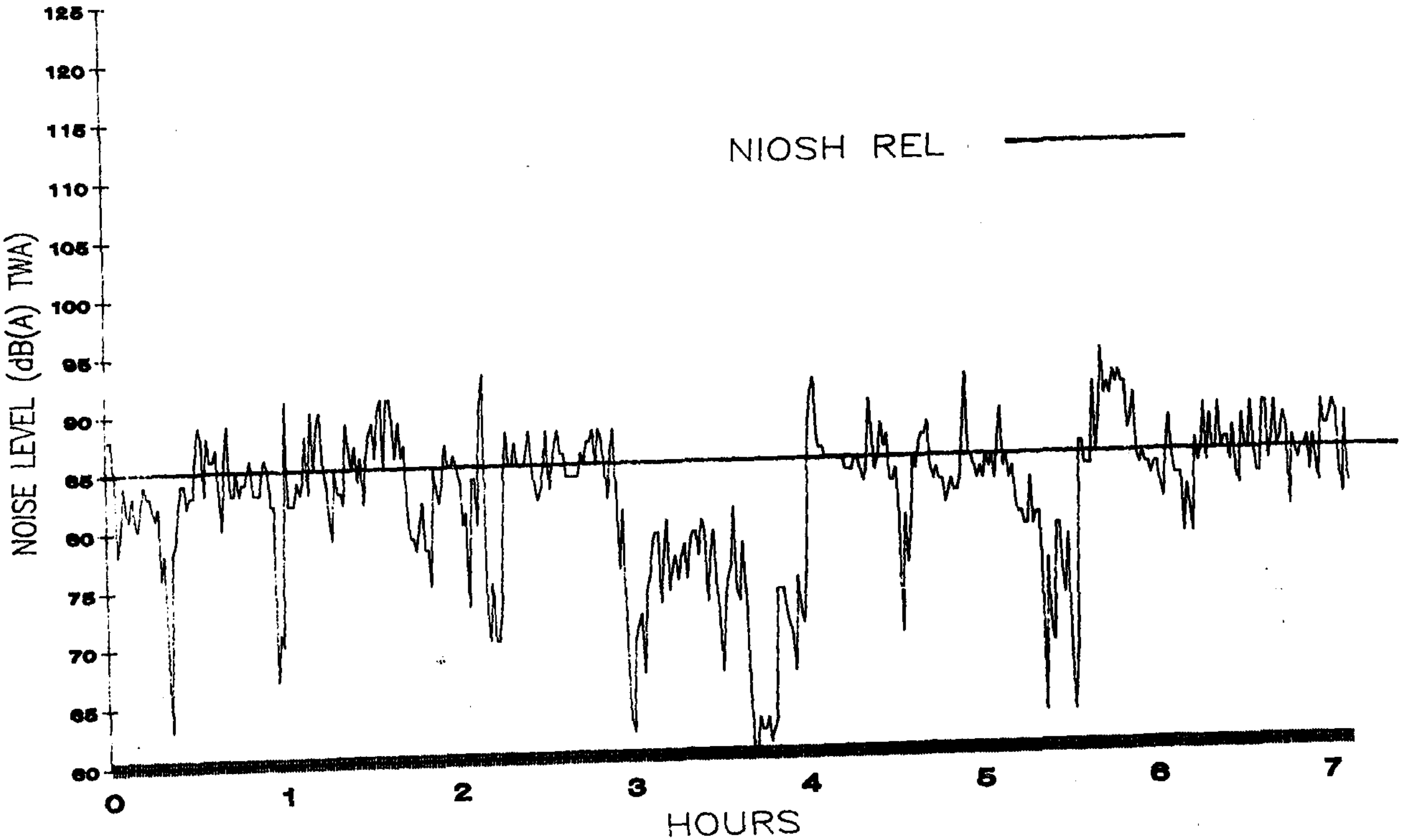


HETA 87-413

St. Lucia Noise Survey

Heineken Brewery

Engine Room Operator

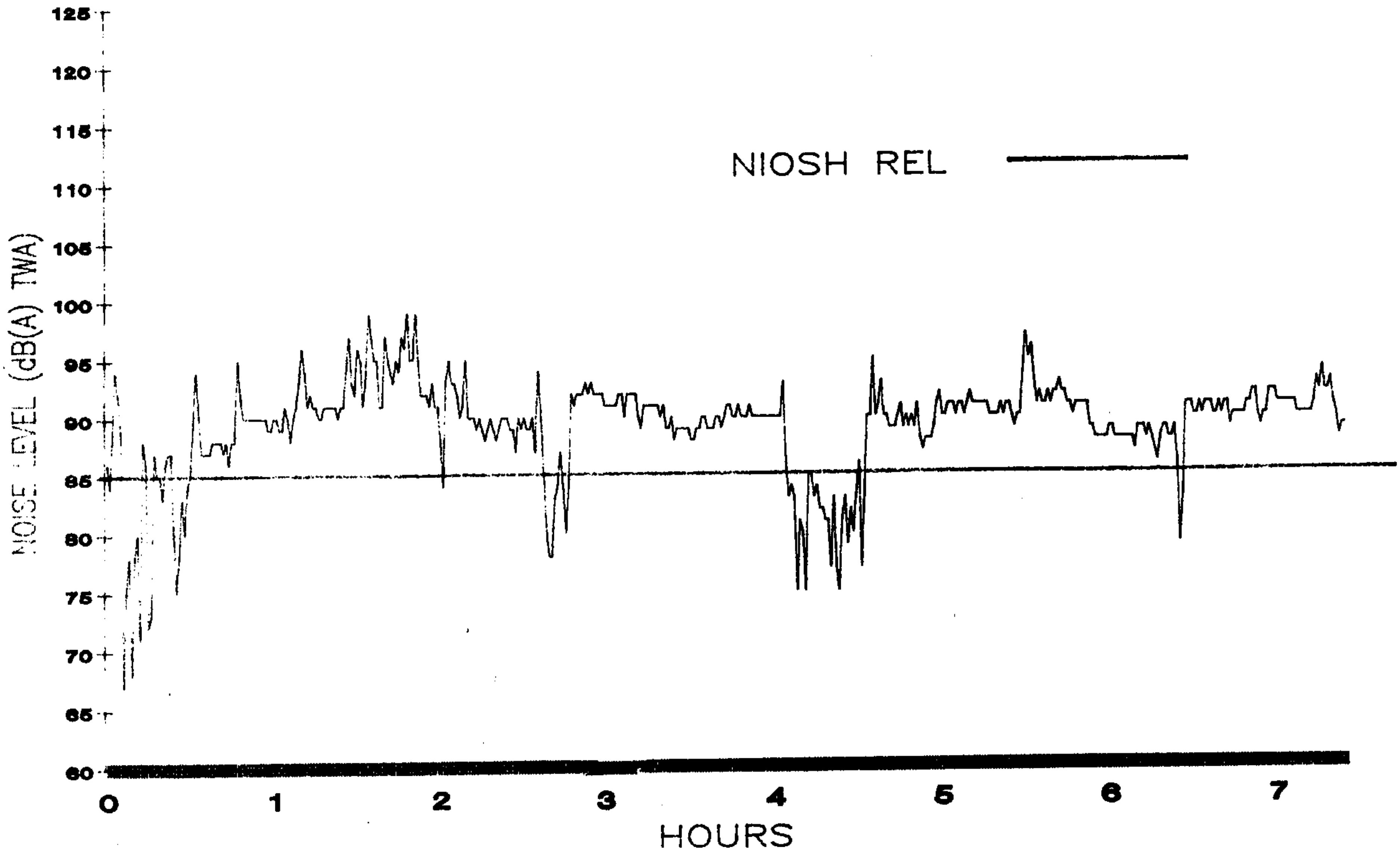


HETA 87-413

St. Lucia Noise Survey

Heineken Brewery

Bottling Hall - Pasteurizing Machine Operator

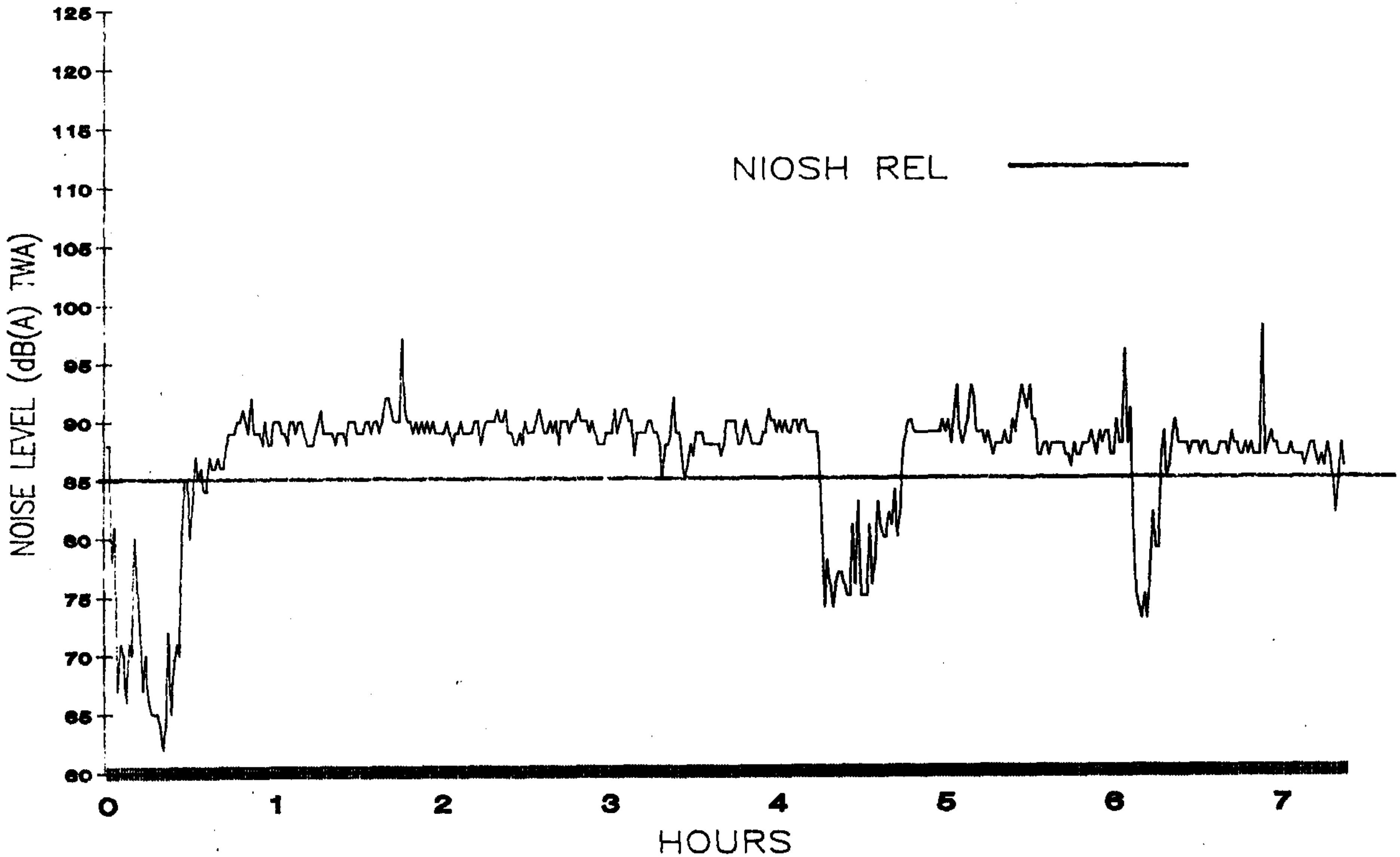


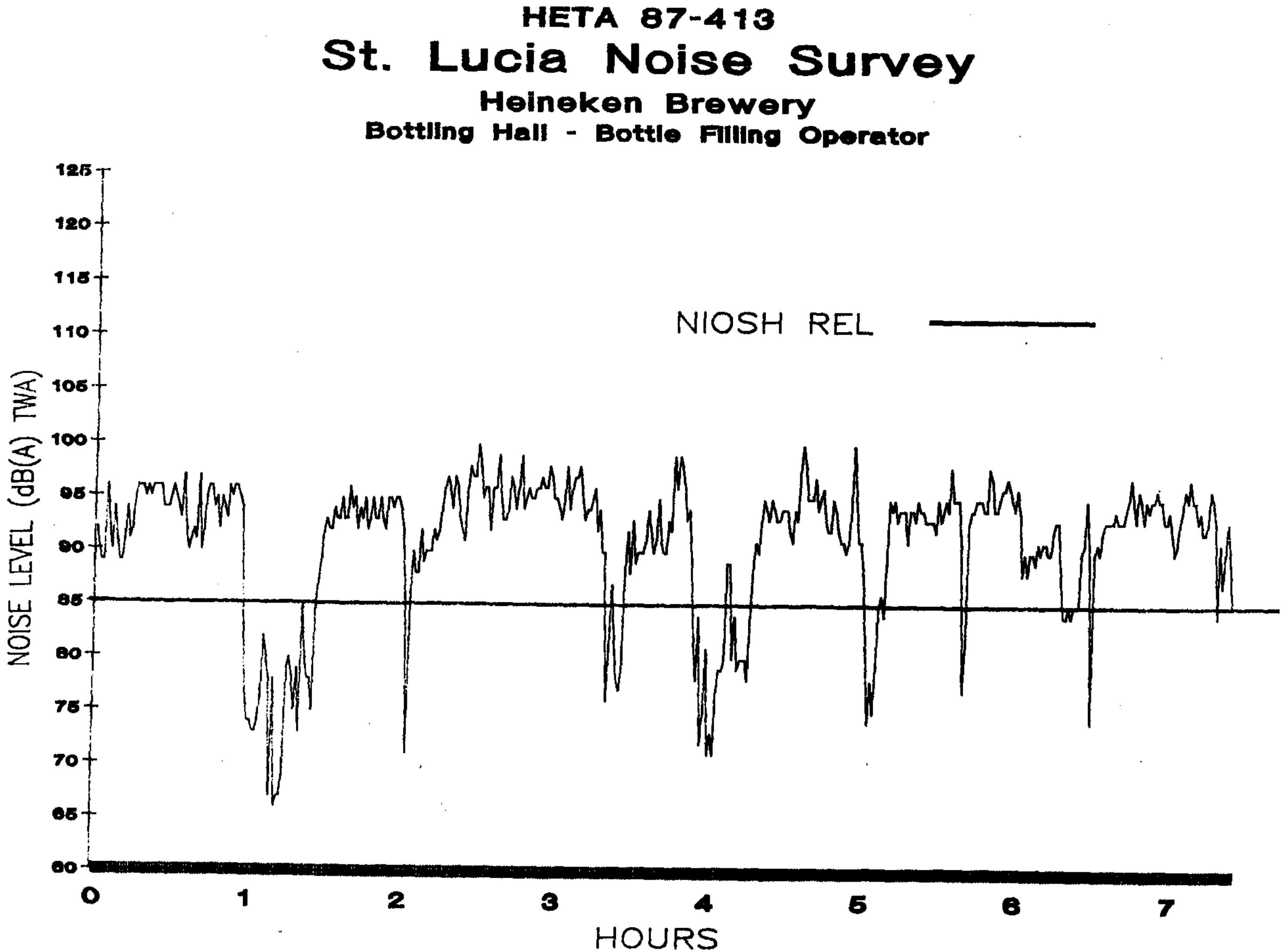
HETA 87-413

St. Lucia Noise Survey

Heineken Brewery

Bottling Hall - Bottle Labeling Operator





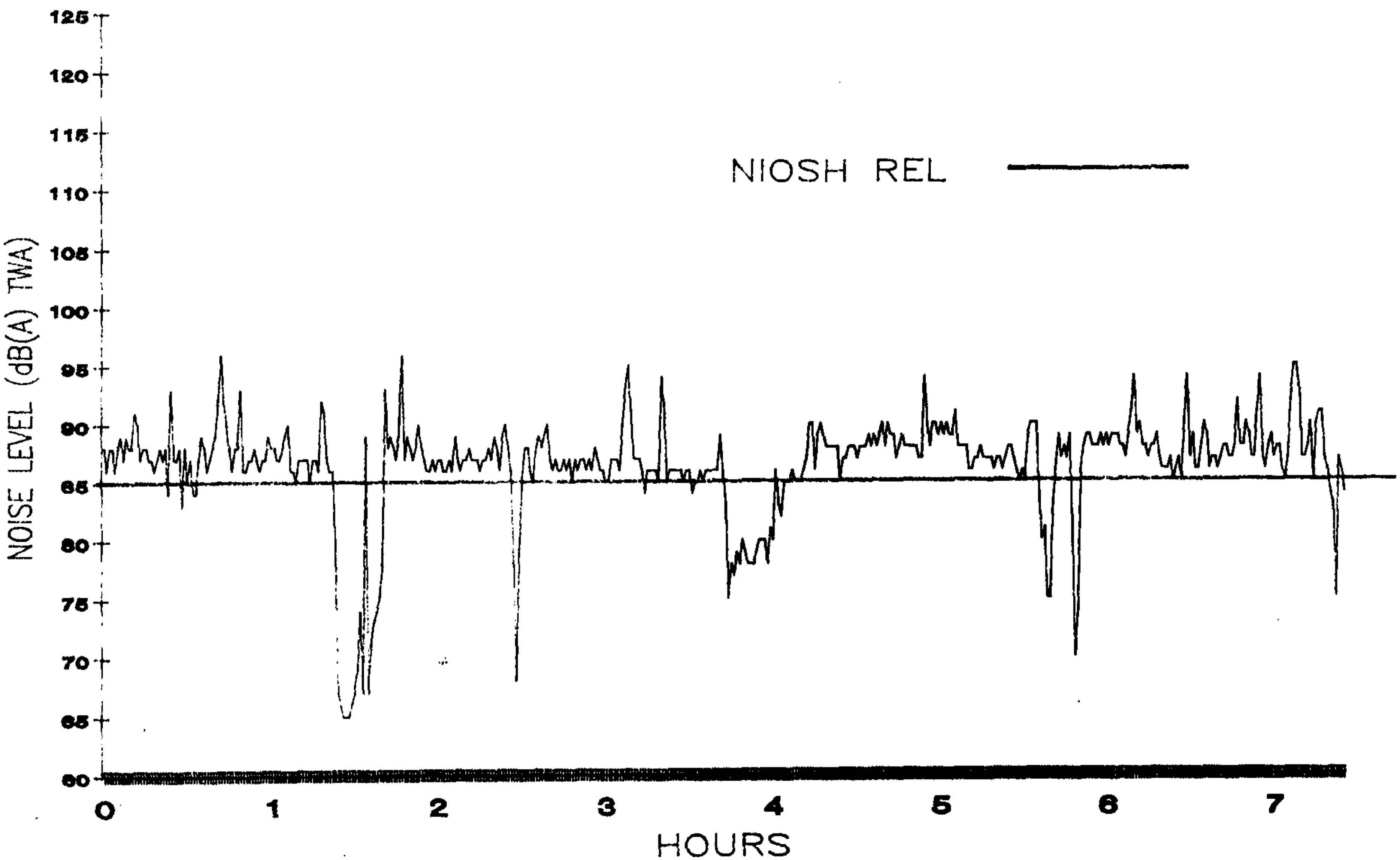
HETA 87-413
St. Lucia Noise Survey
Heineken Brewery
Bottling Hall - Bottle Filling Operator
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
HOURS

HETA 87-413

St. Lucia Noise Survey

Heineken Brewery

Bottling Hall - Bottle Washer Operator

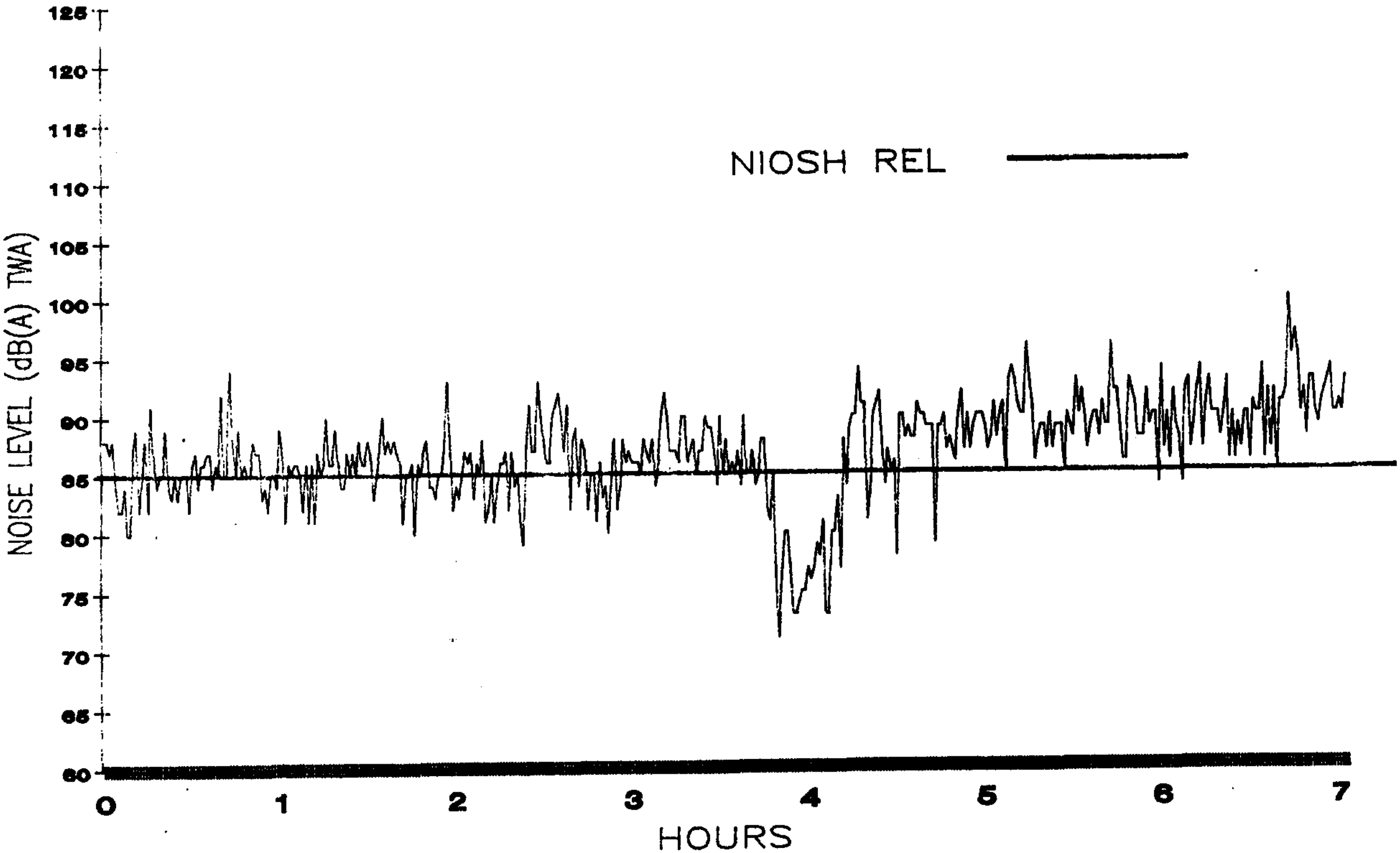


HETA 87-413

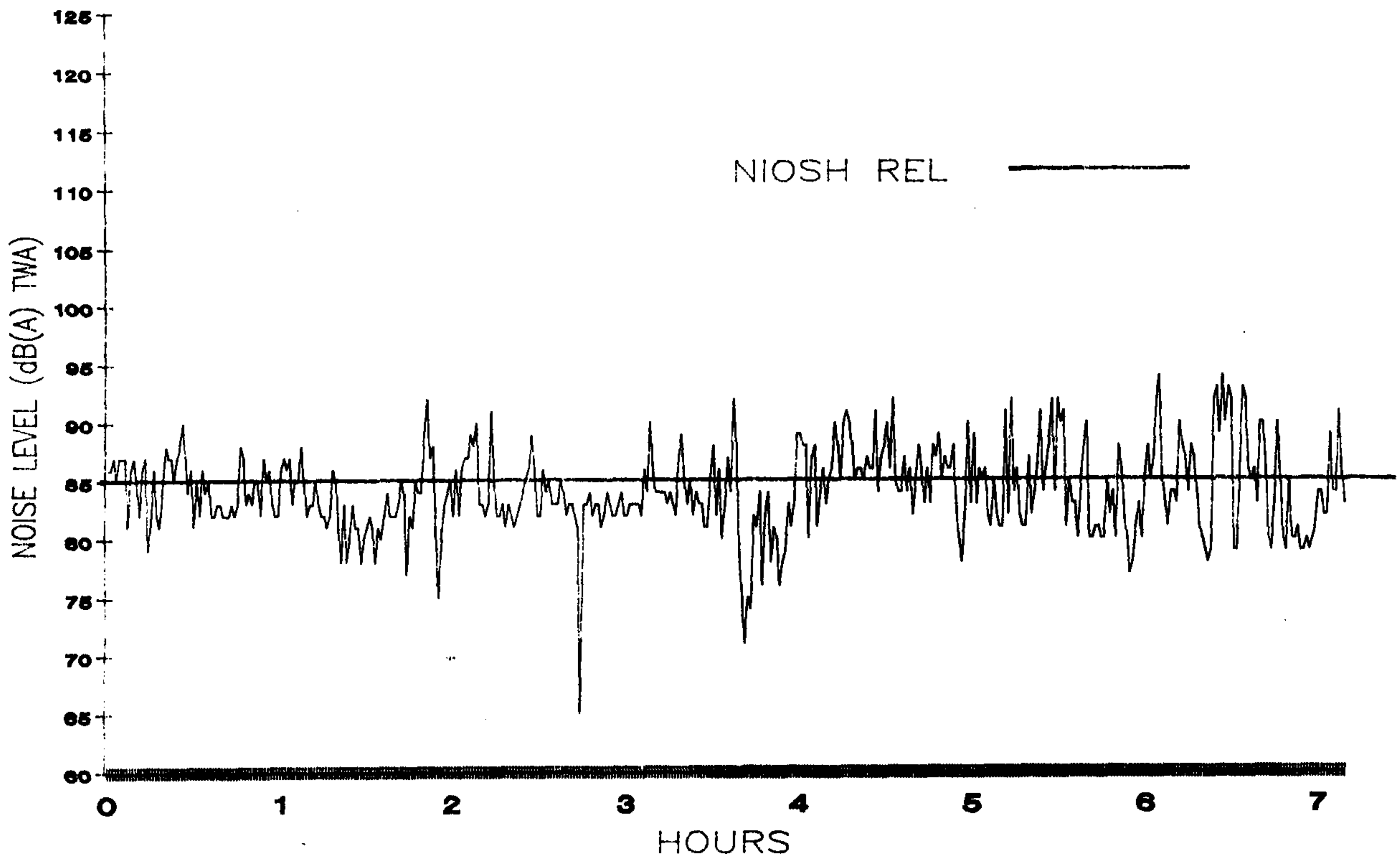
St. Lucia Noise Survey

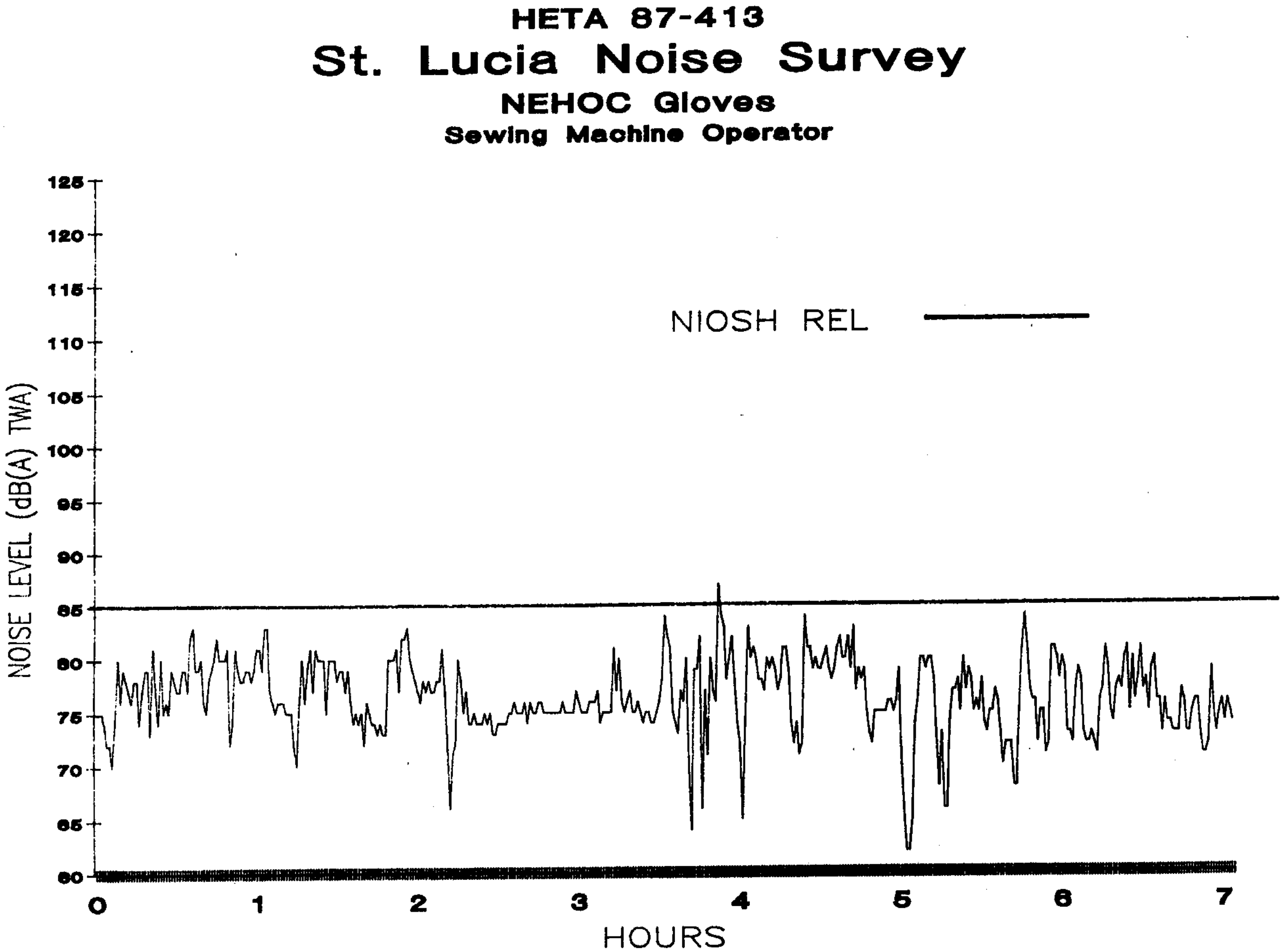
Heineken Brewery

Fork Lift Operator



HETA 87-413
St. Lucia Noise Survey
NEHOC Gloves
Glove Cutter Operator



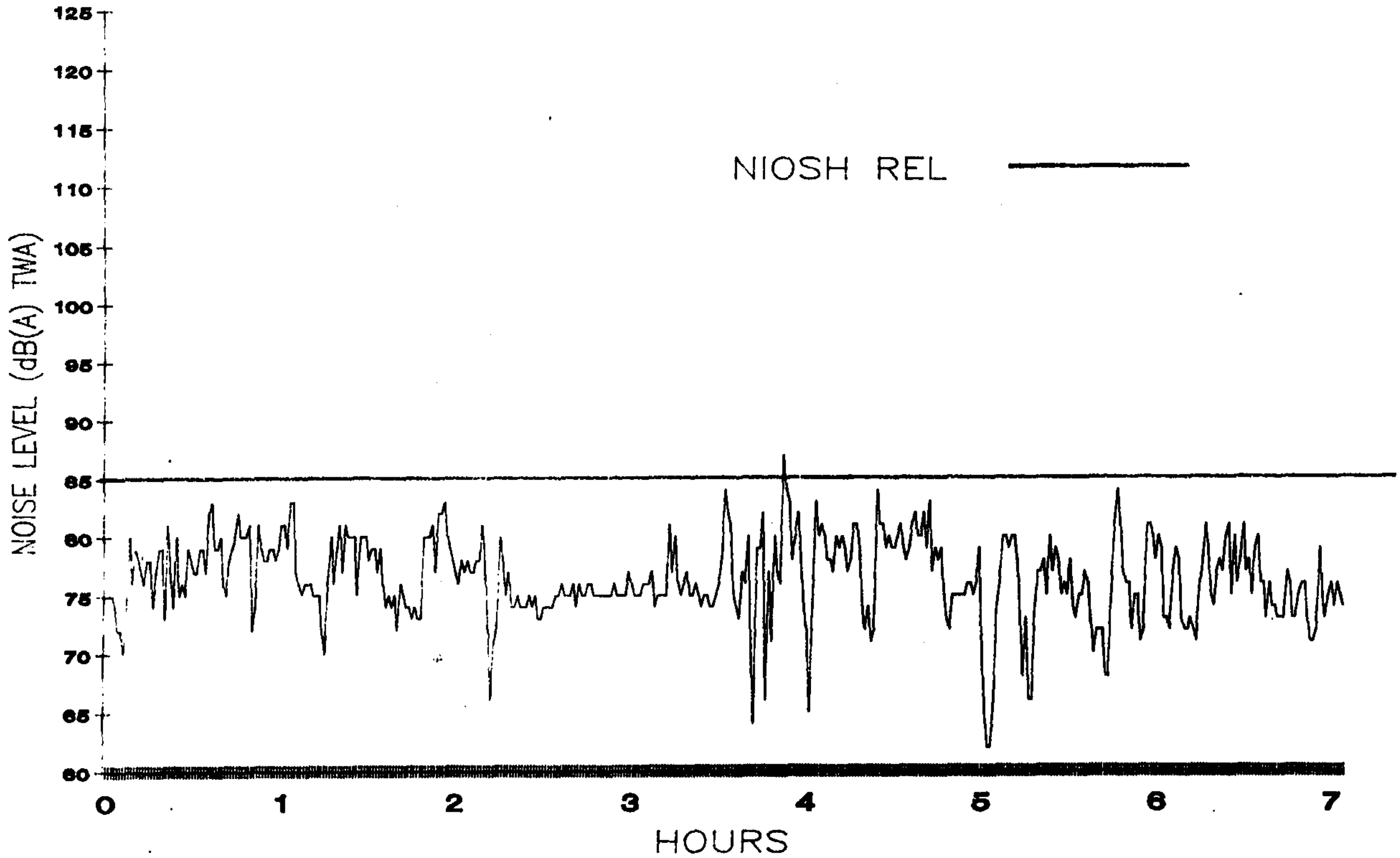

HETA 87-413
St. Lucia Noise Survey
NEHOC Gloves
Sewing Machine Operator
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
HOURS

HETA 87-413

St. Lucia Noise Survey

NEHOC Gloves

Sizing & Packing Table

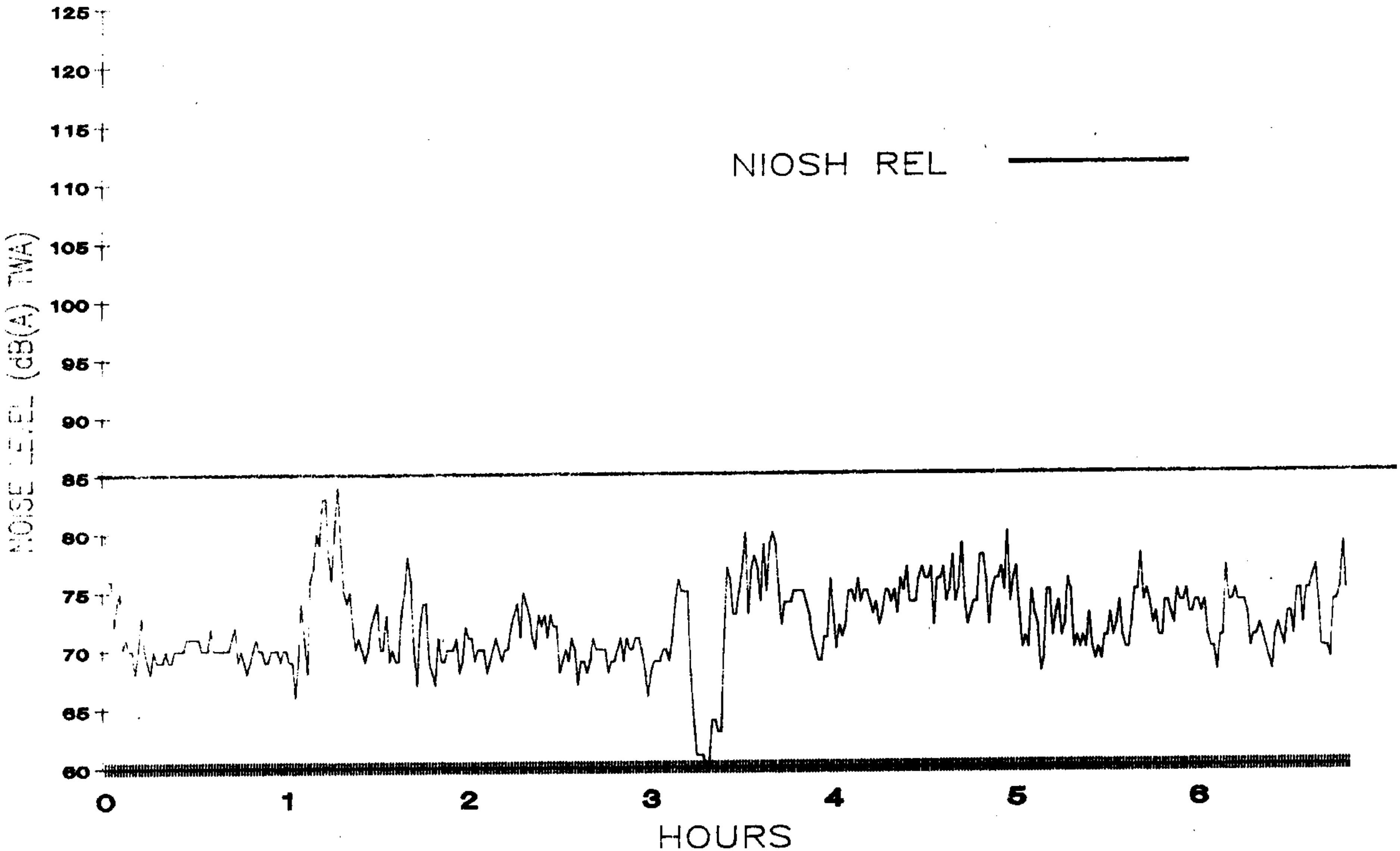


HETA 87-413

St. Lucia Noise Survey

Data Delay Devices

Integrated Circuit Table

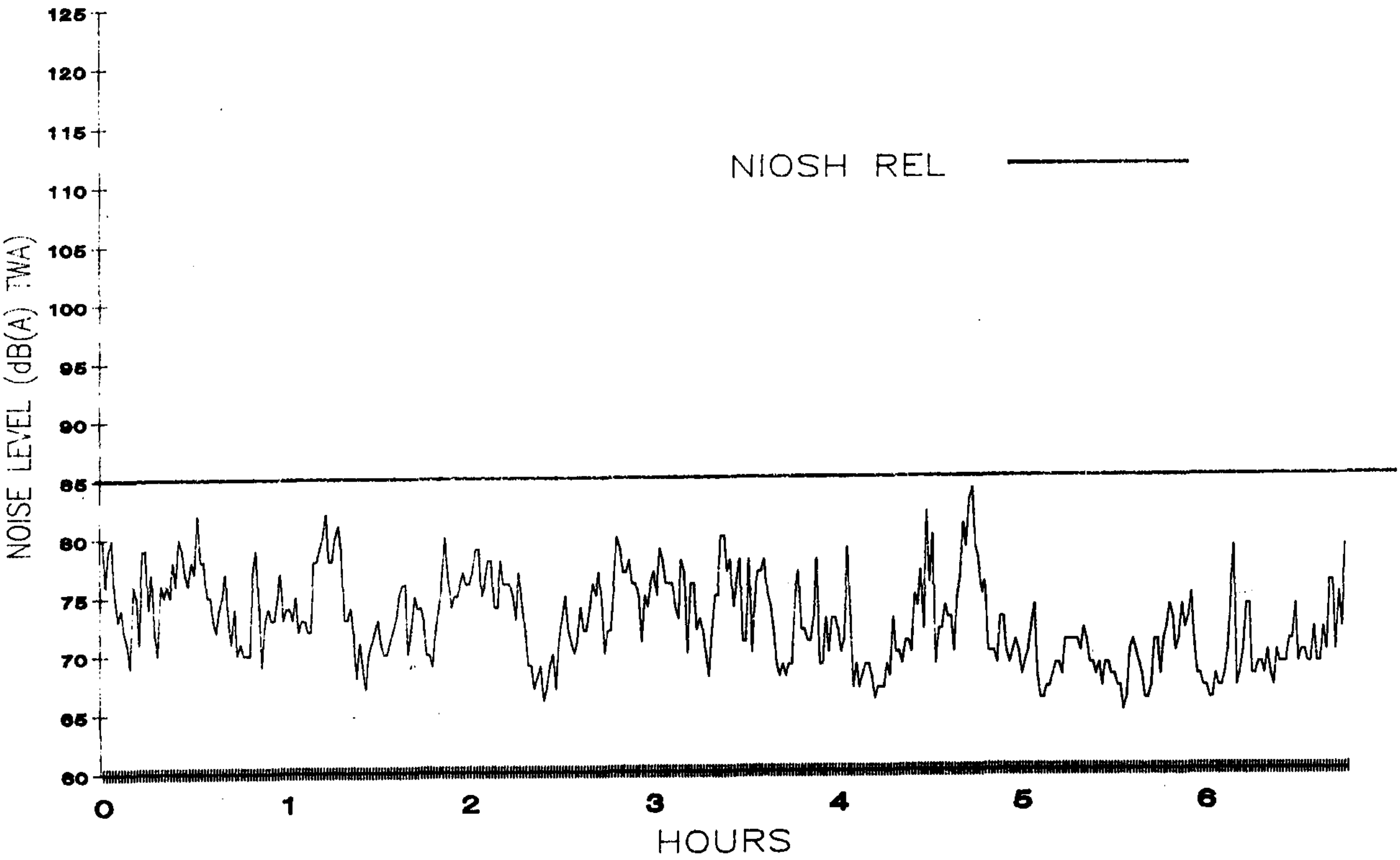


HETA 87-413

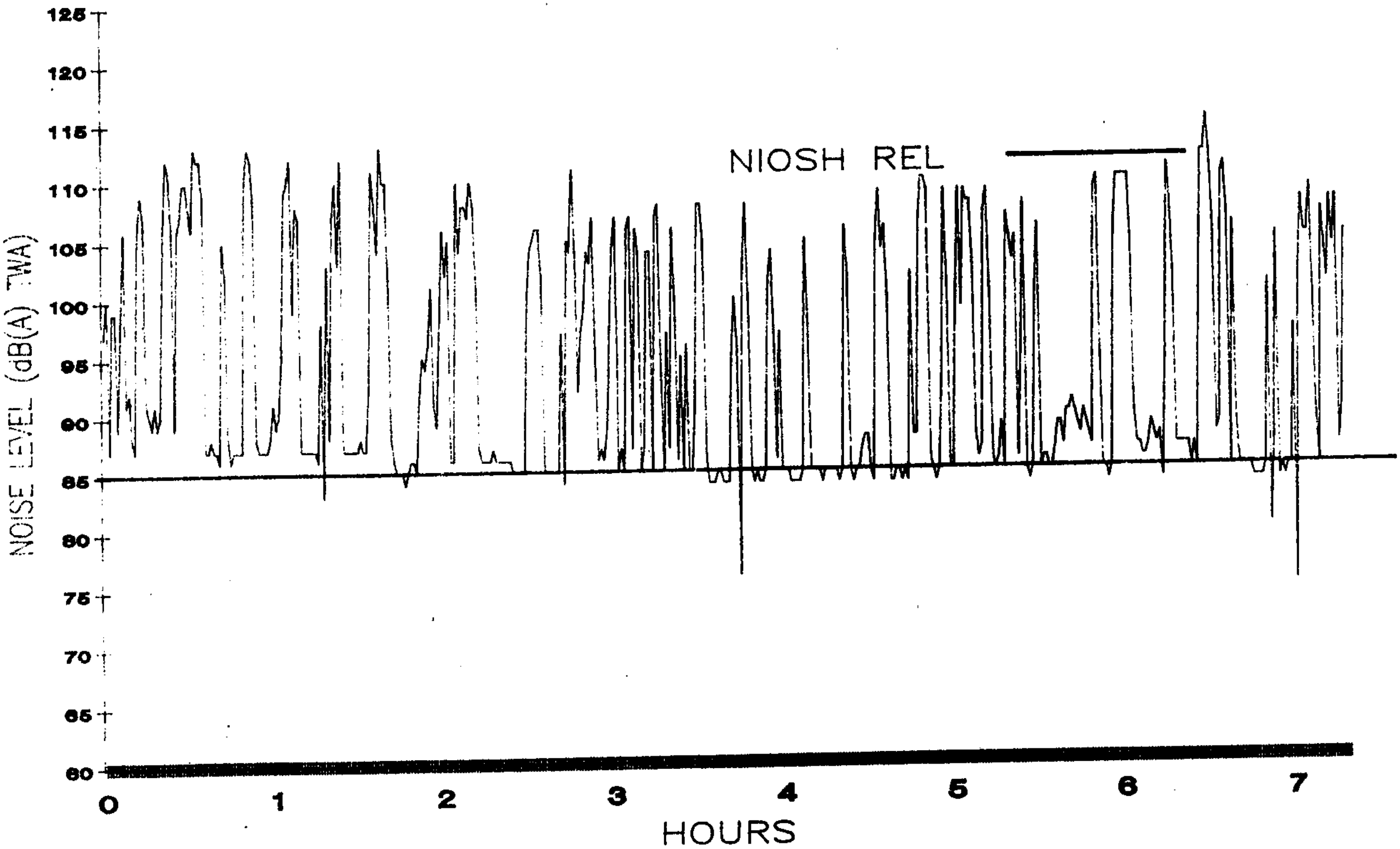
St. Lucia Noise Survey

Data Delay Devices

Packing & Shipping Table



HETA 87-413
St. Lucia Noise Survey
LUCELEC - Union Station
Power Plant Operator

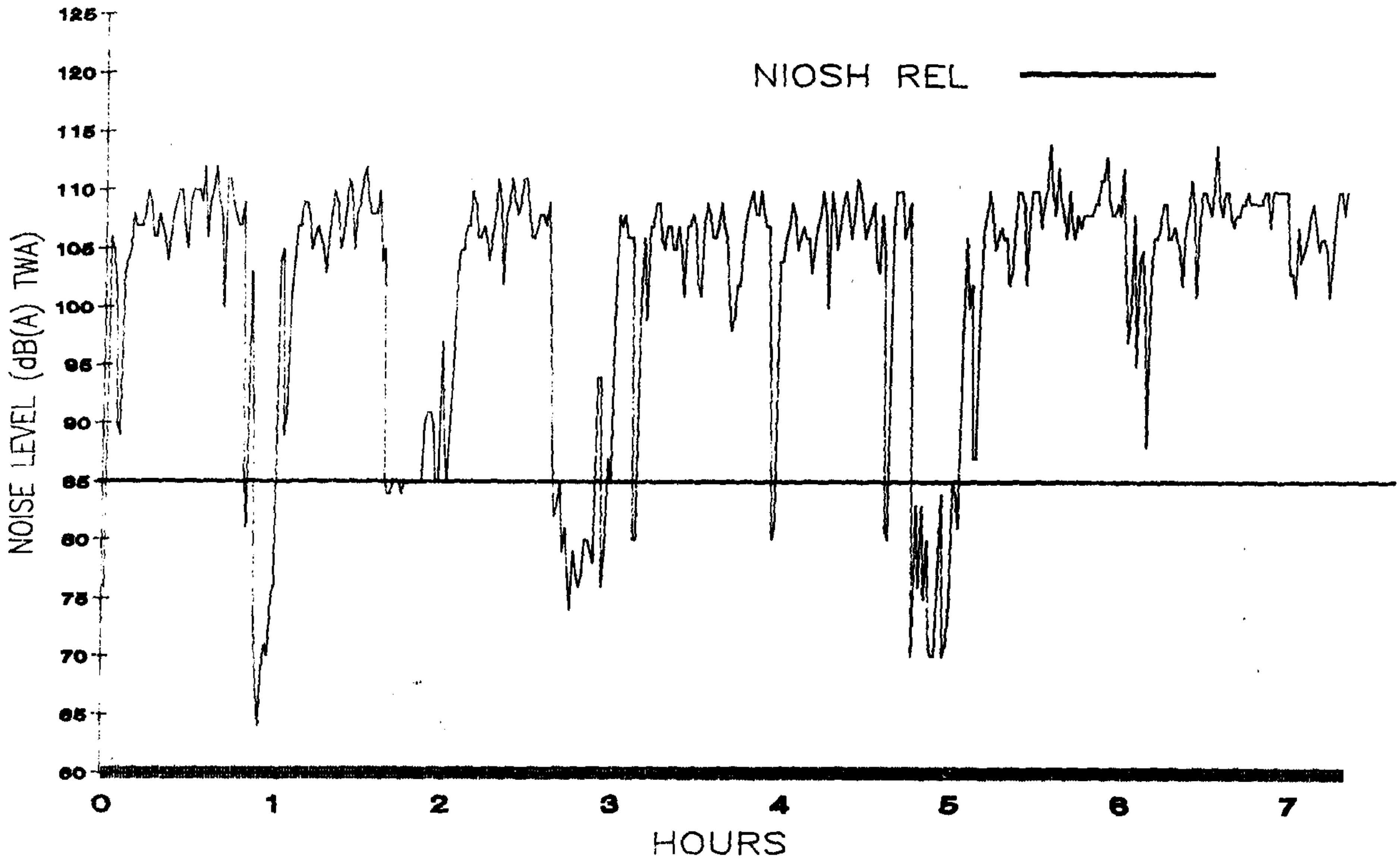


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Power Plant Operator "B"

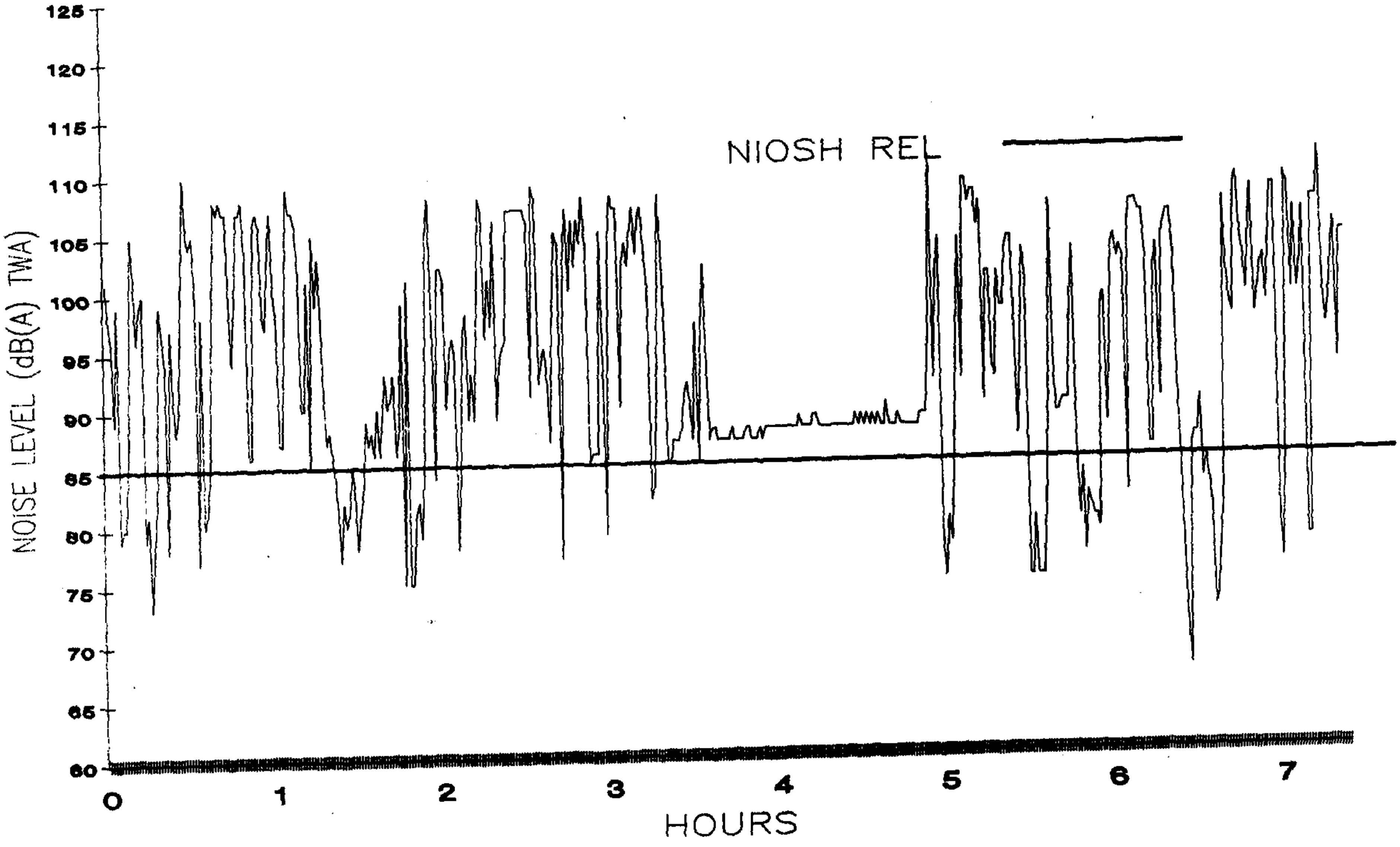


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Mechanic

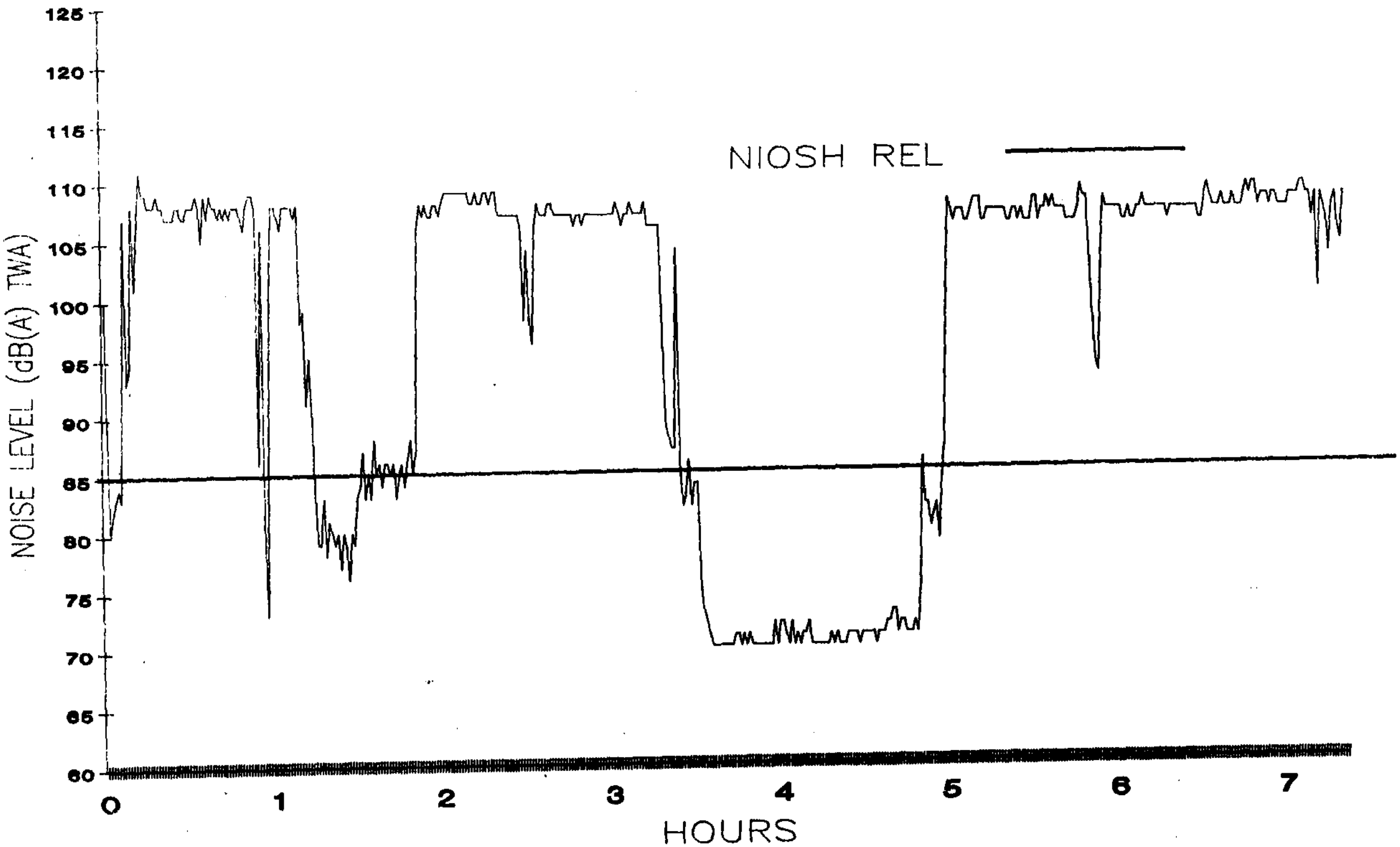


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Mechanic "B"

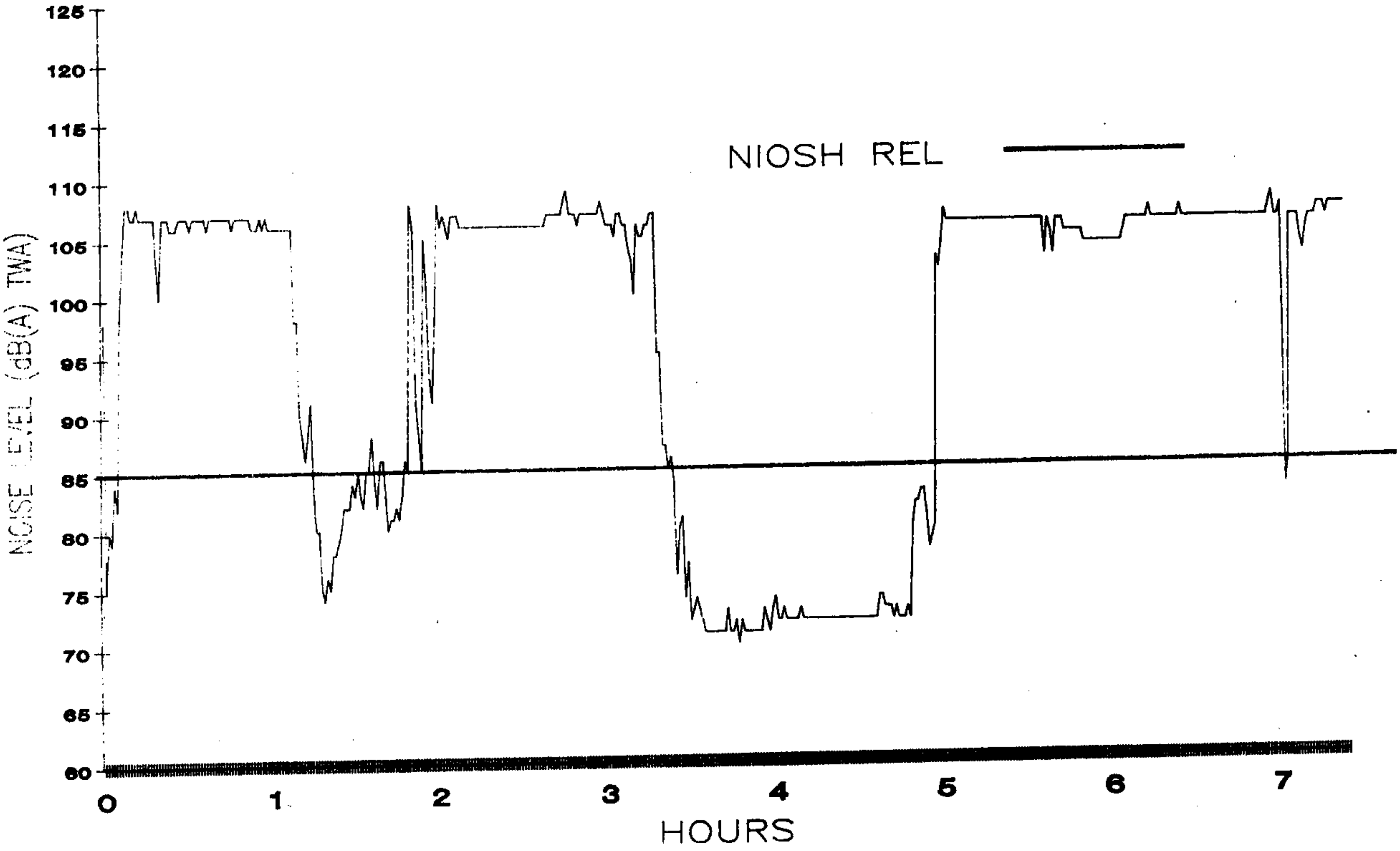


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Mechanic "C"

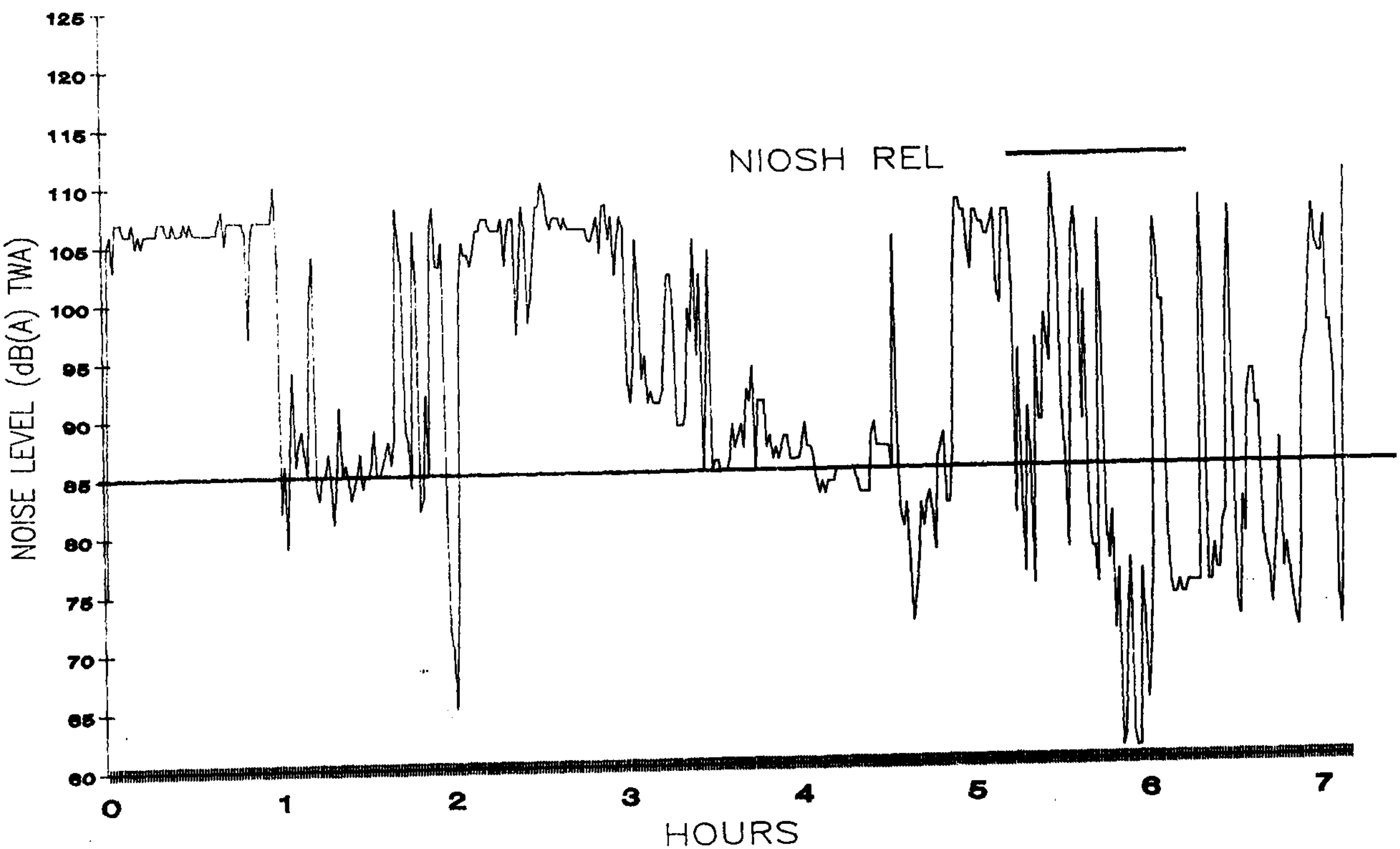


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Mechanic "D"

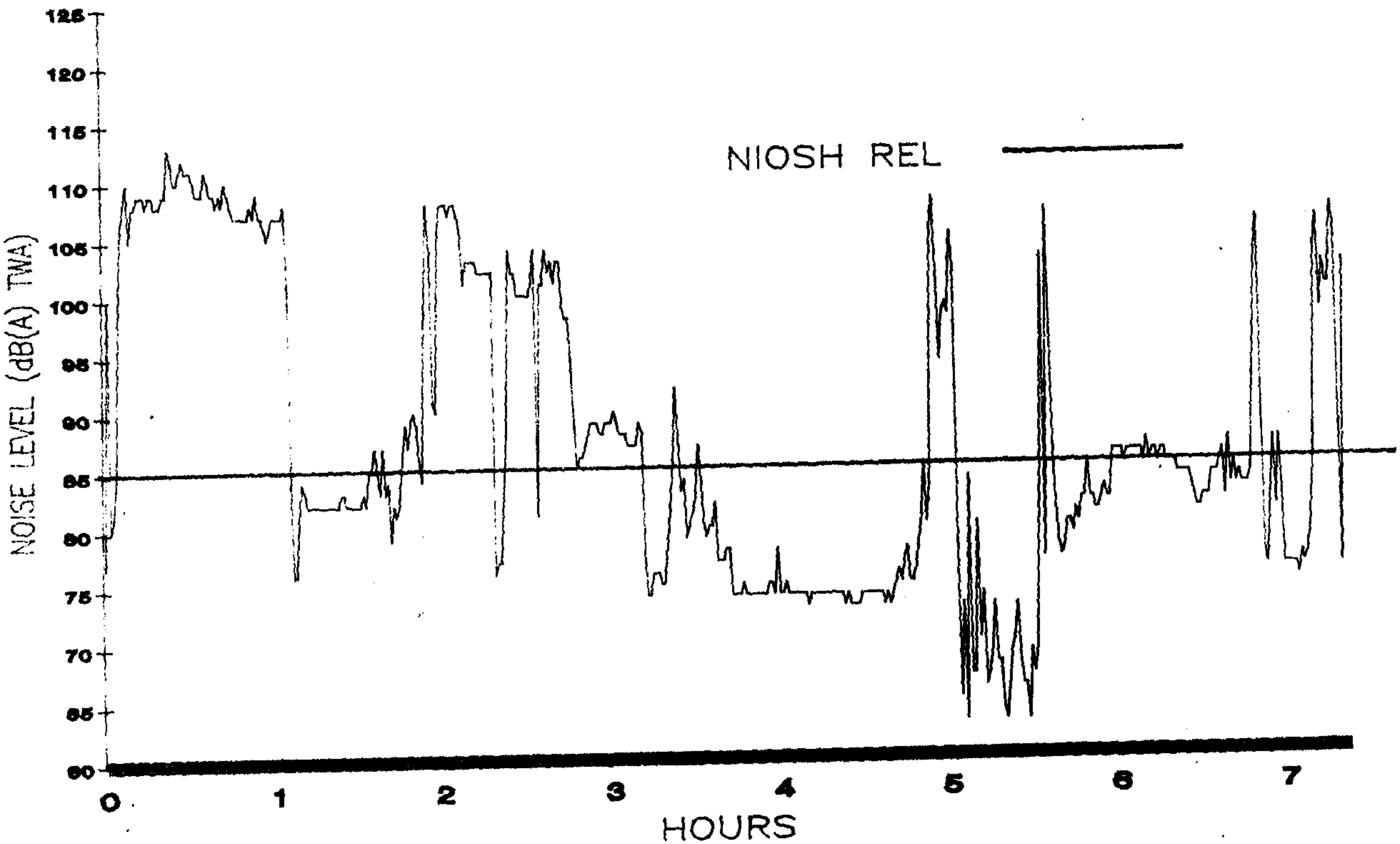


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Mechanic "E"

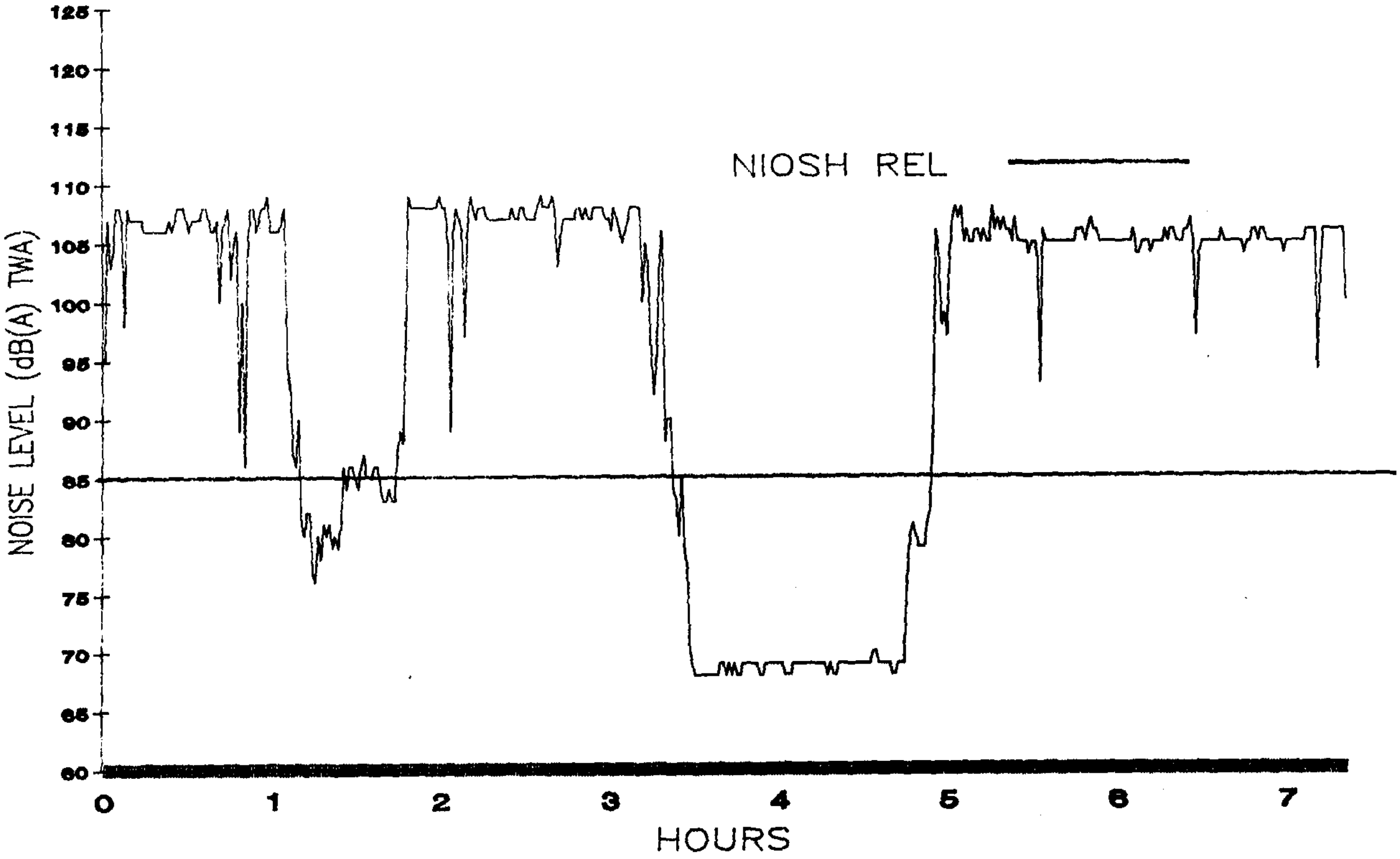


HETA 87-413

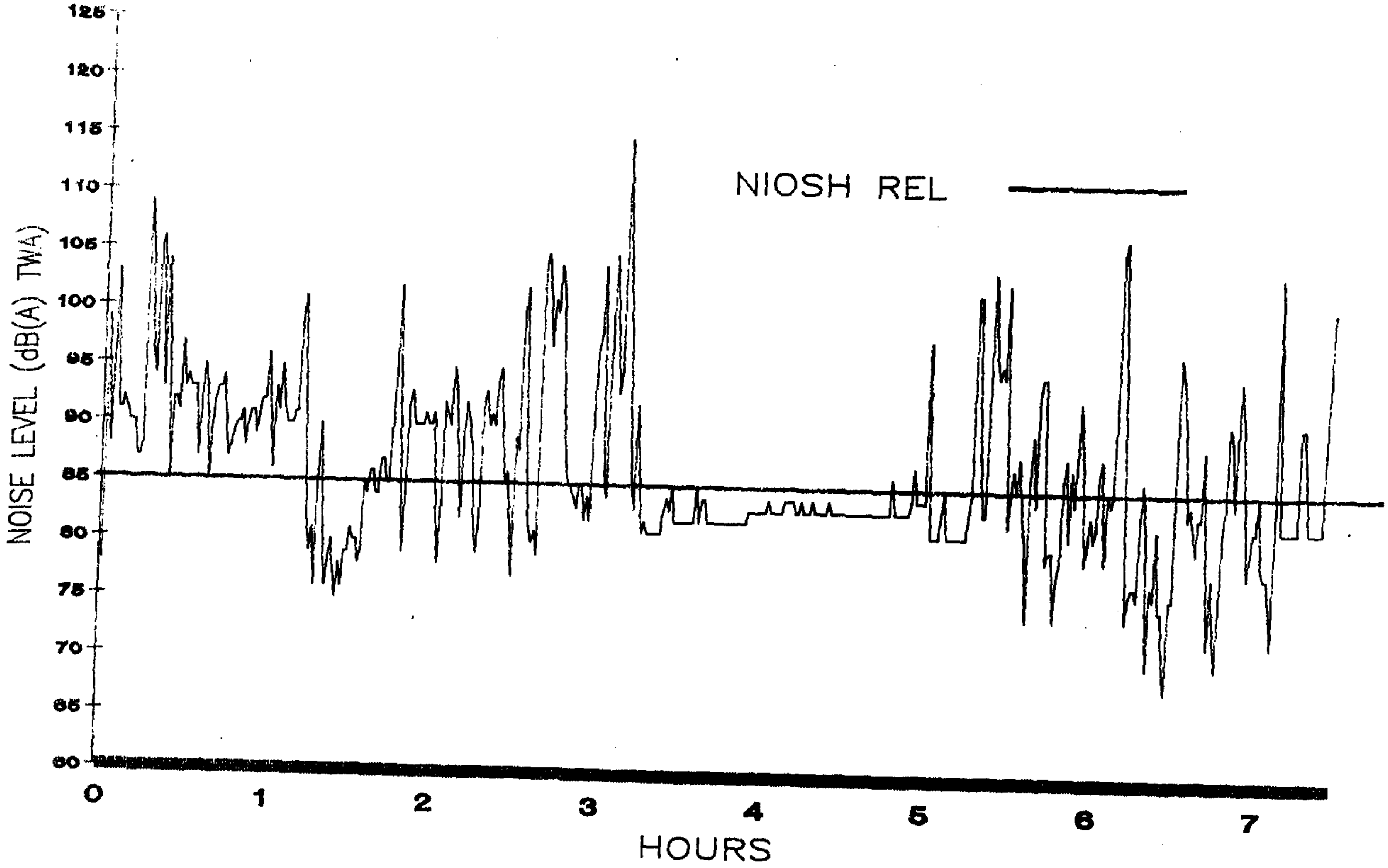
St. Lucia Noise Survey

LUCELEC - Union Station

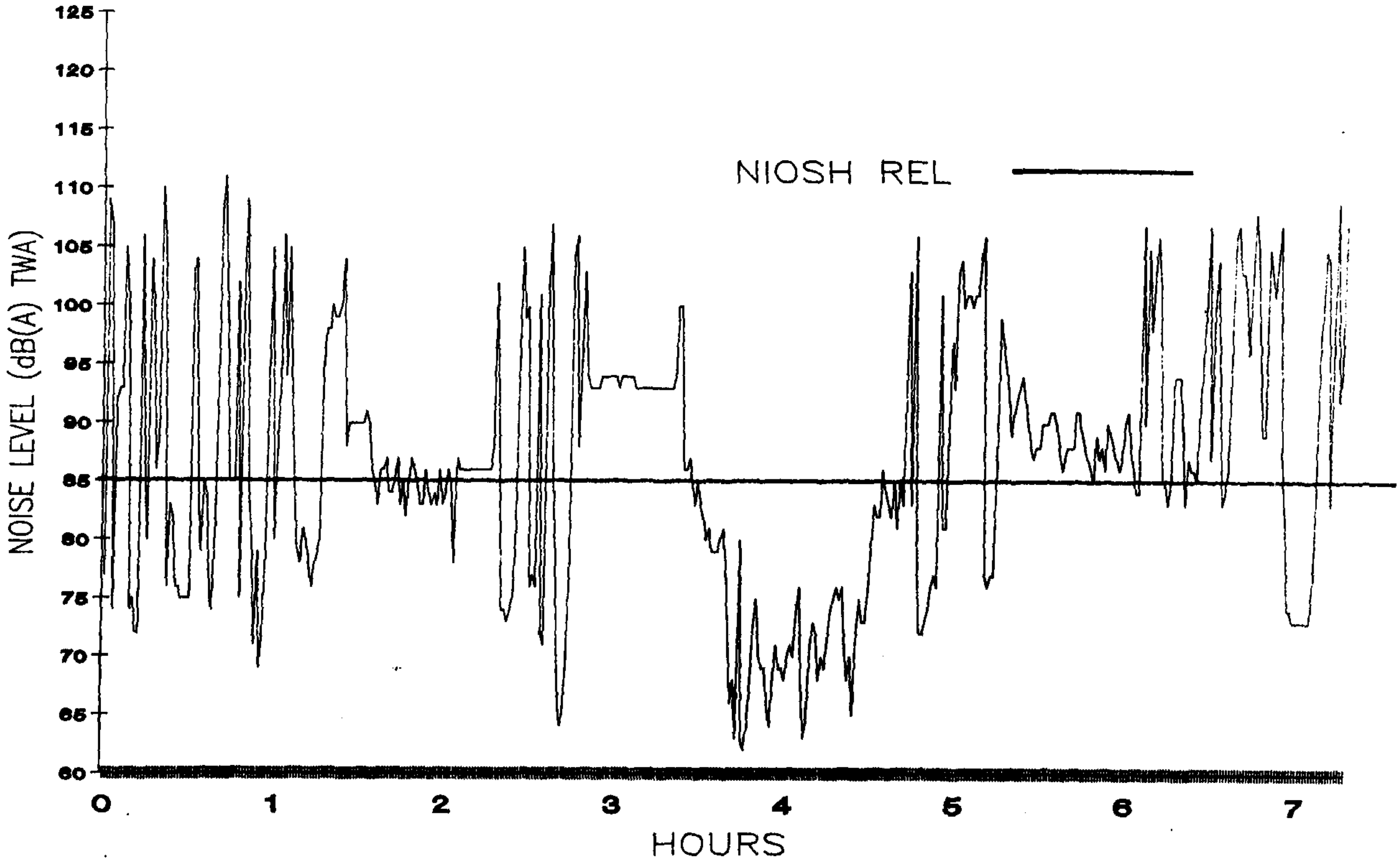
Mechanic "F"



HETA 87-413
St. Lucia Noise Survey
LUCELEC - Union Station
Electrician



HETA 87-413
St. Lucia Noise Survey
LUCELEC - Union Station
Waste Clean Up

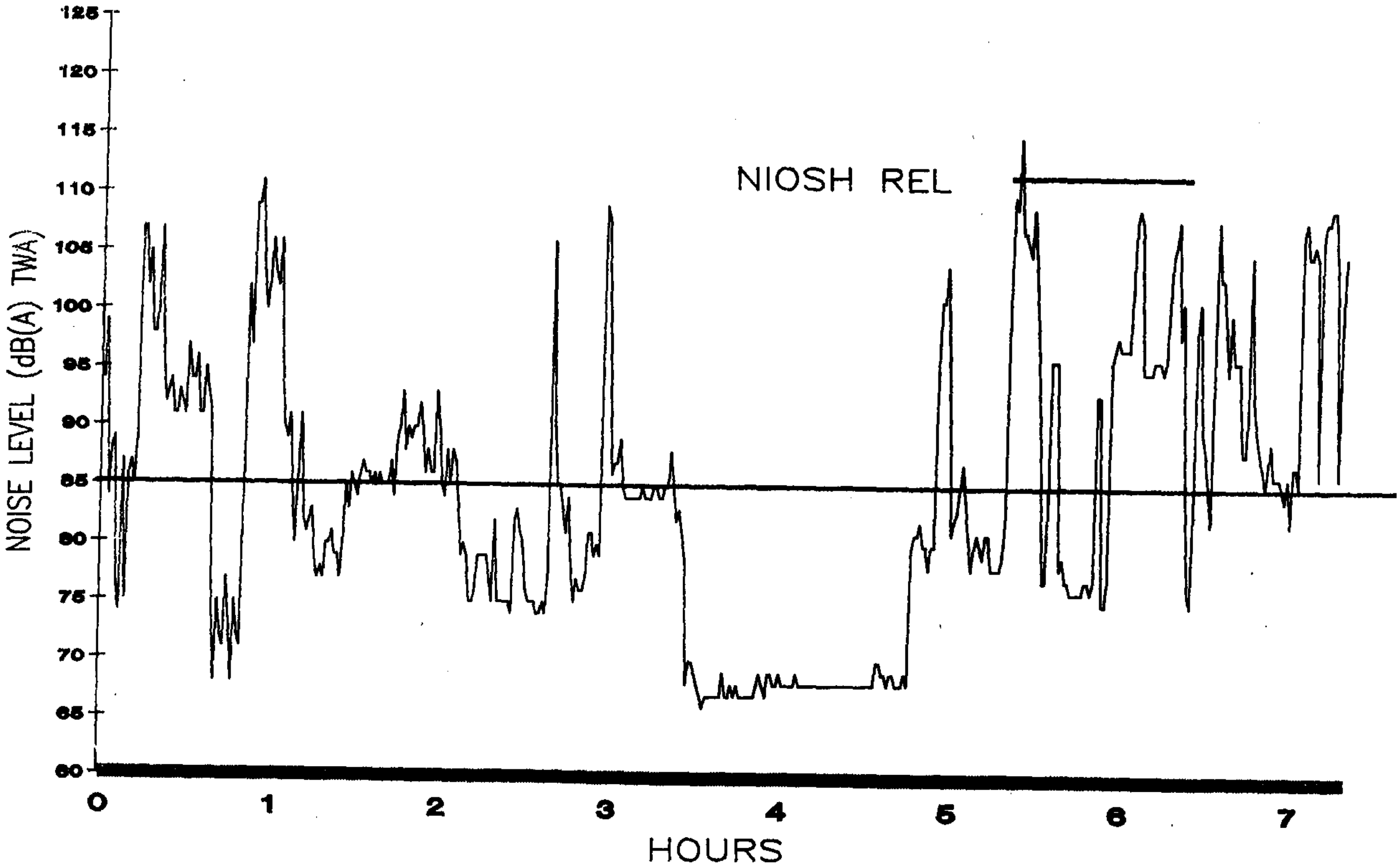


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Waste Clean-Up "B"

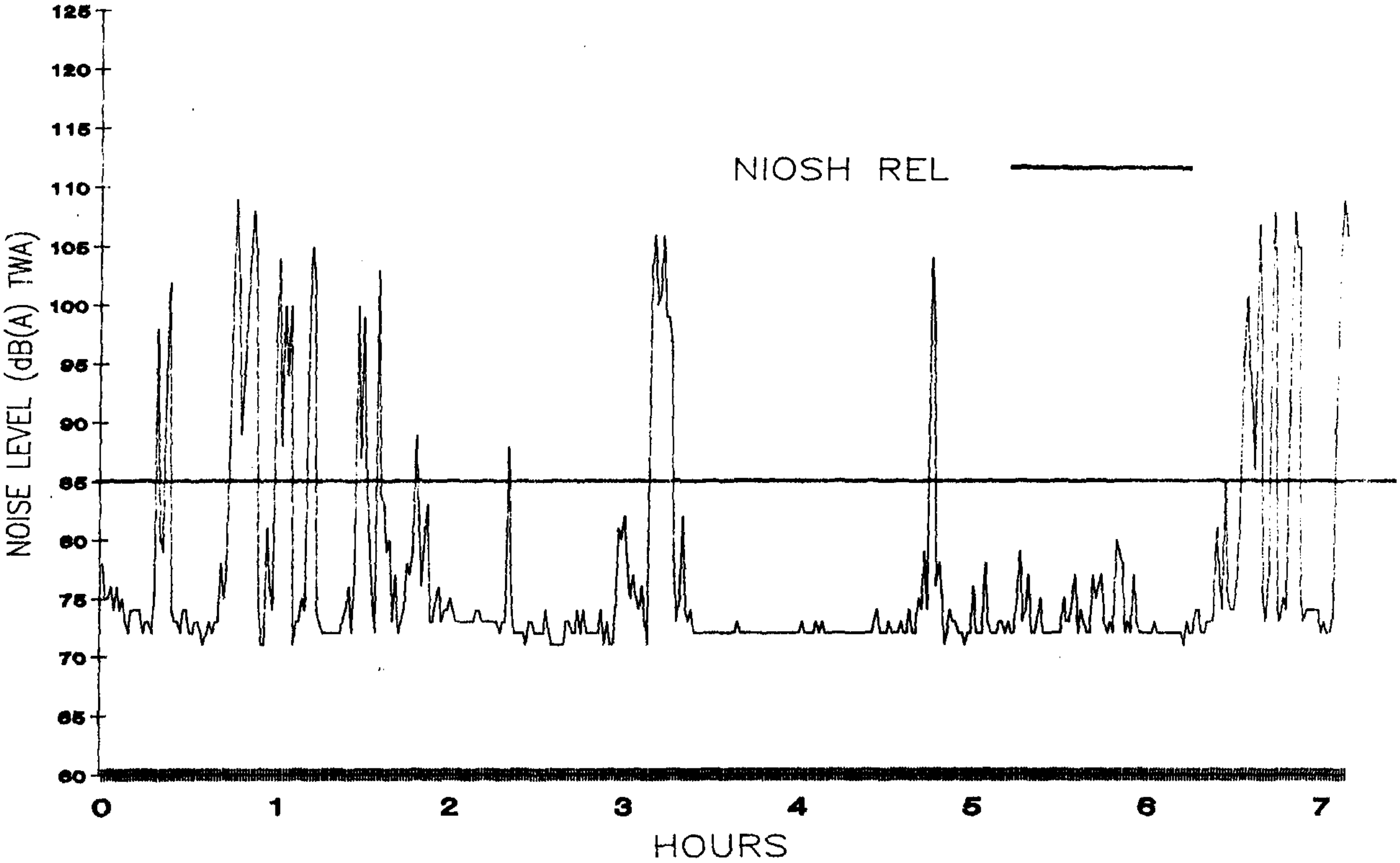


HETA 87-413

St. Lucia Noise Survey

LUCELEC - Union Station

Office Clerk

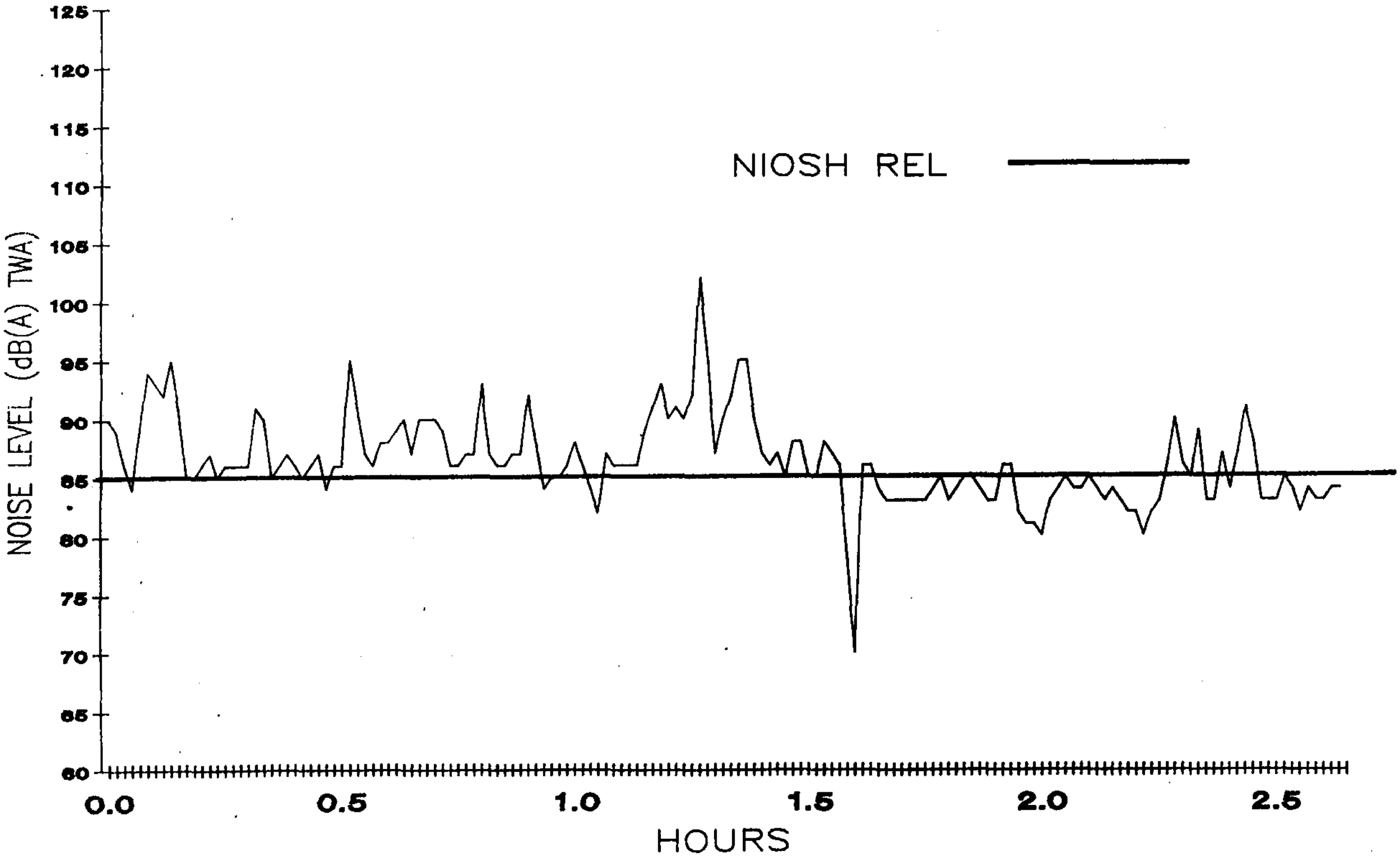


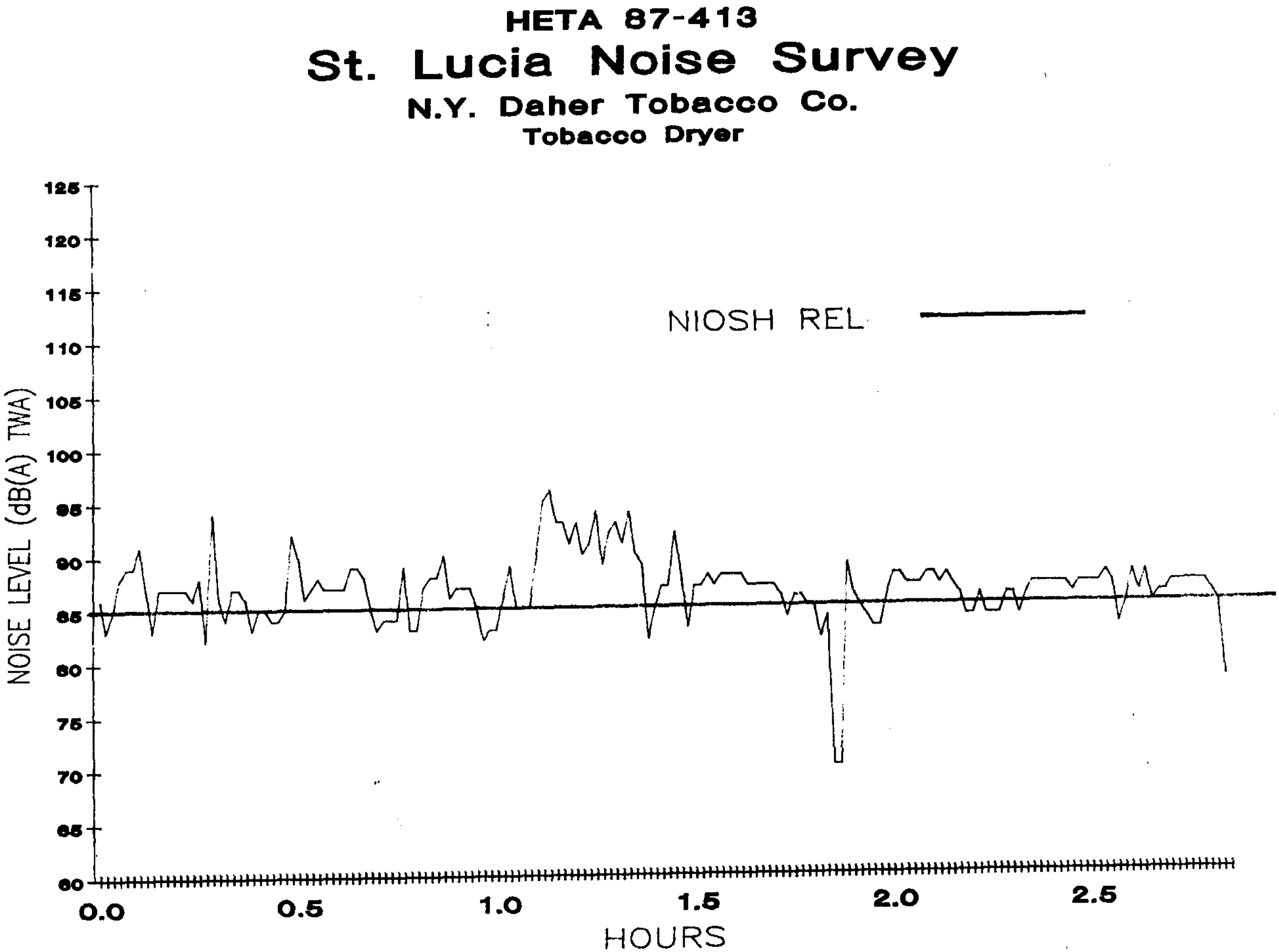
HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Tobacco Cutter



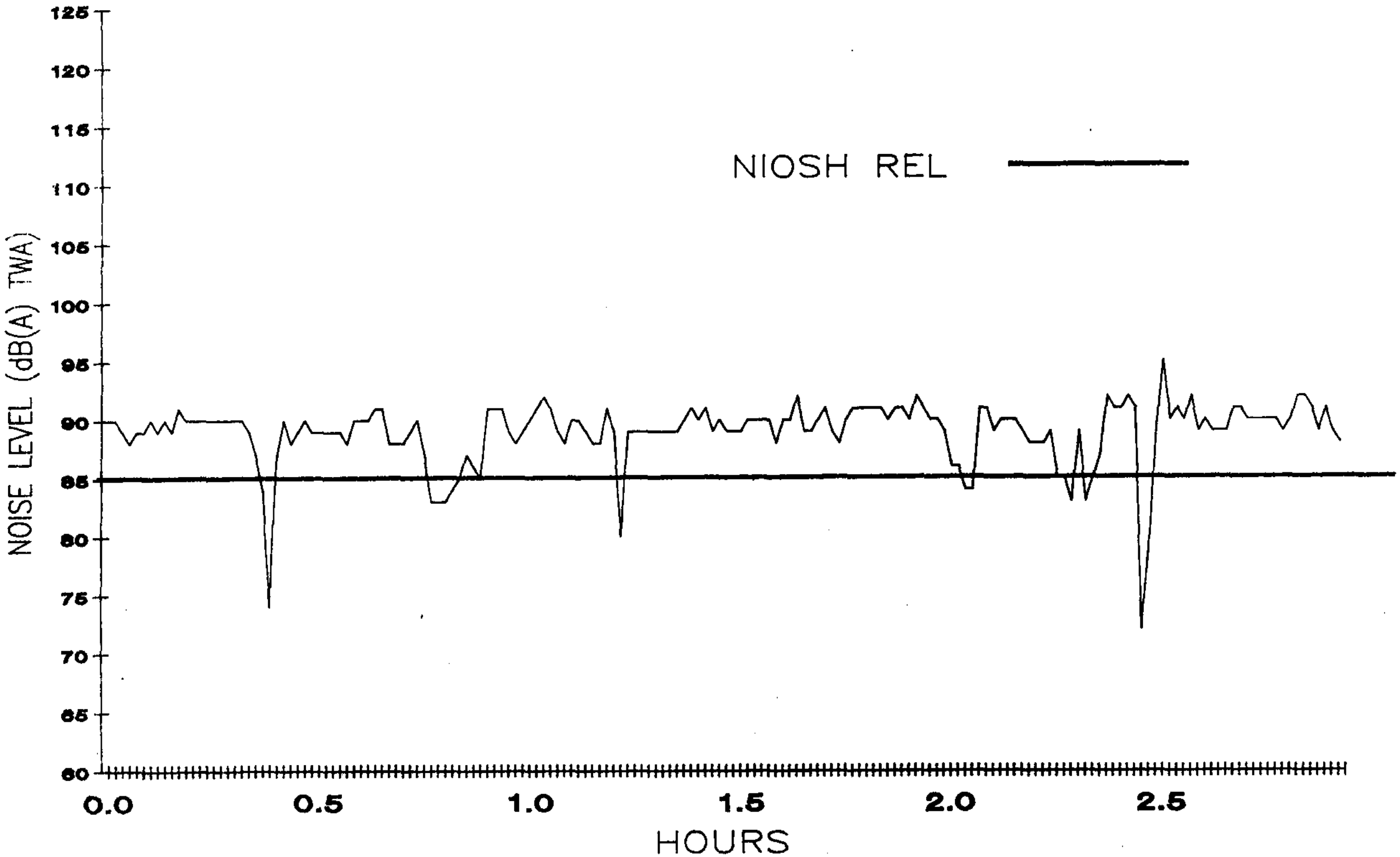

HETA 87-413
St. Lucia Noise Survey
N.Y. Daher Tobacco Co.
Tobacco Dryer
NIOSH REL
NOISE LEVEL (dB(A) TWA)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
0.0
0.5
1.0
1.5
2.0
2.5
HOURS

HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Machine Operator

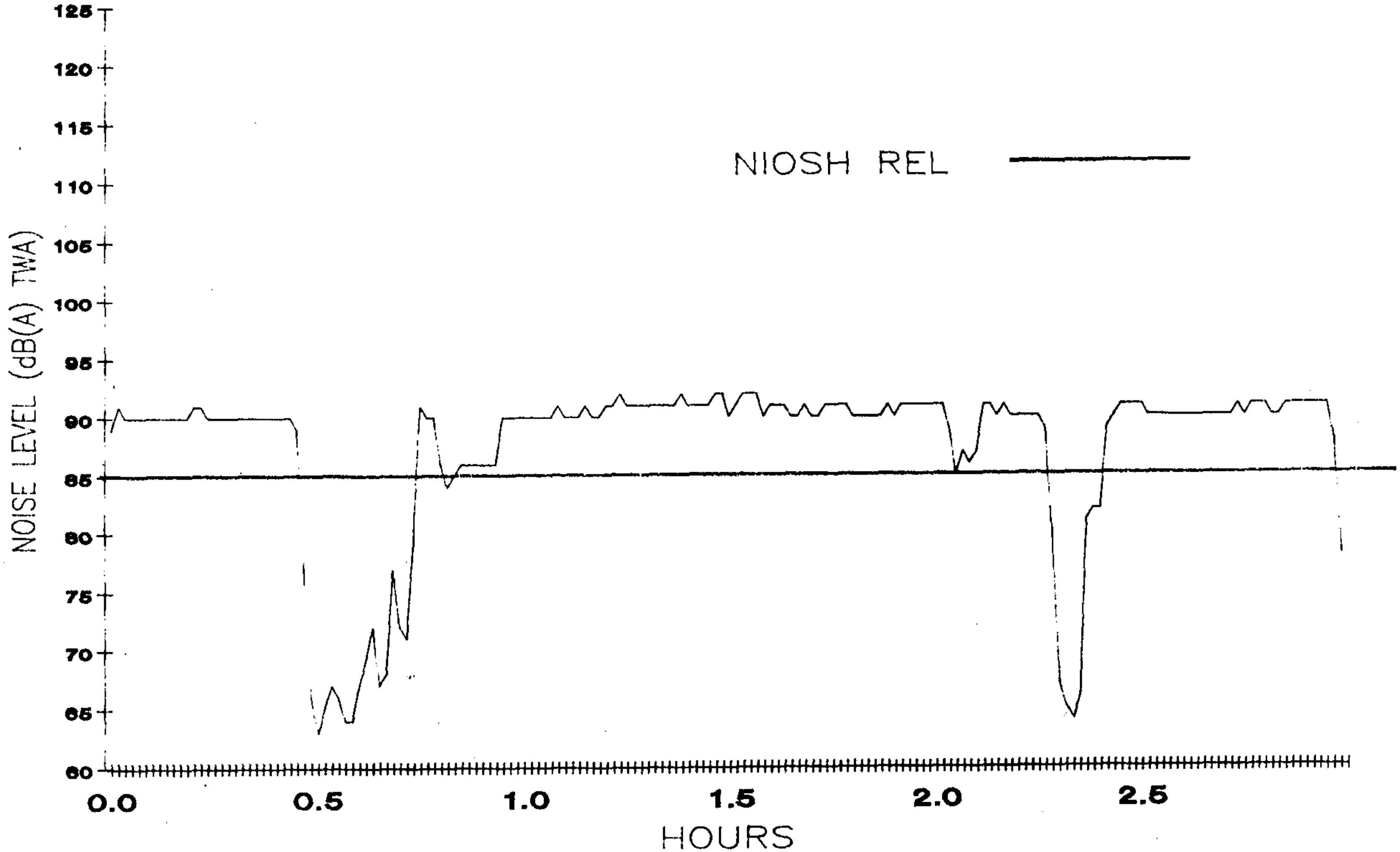


HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Machine Packer

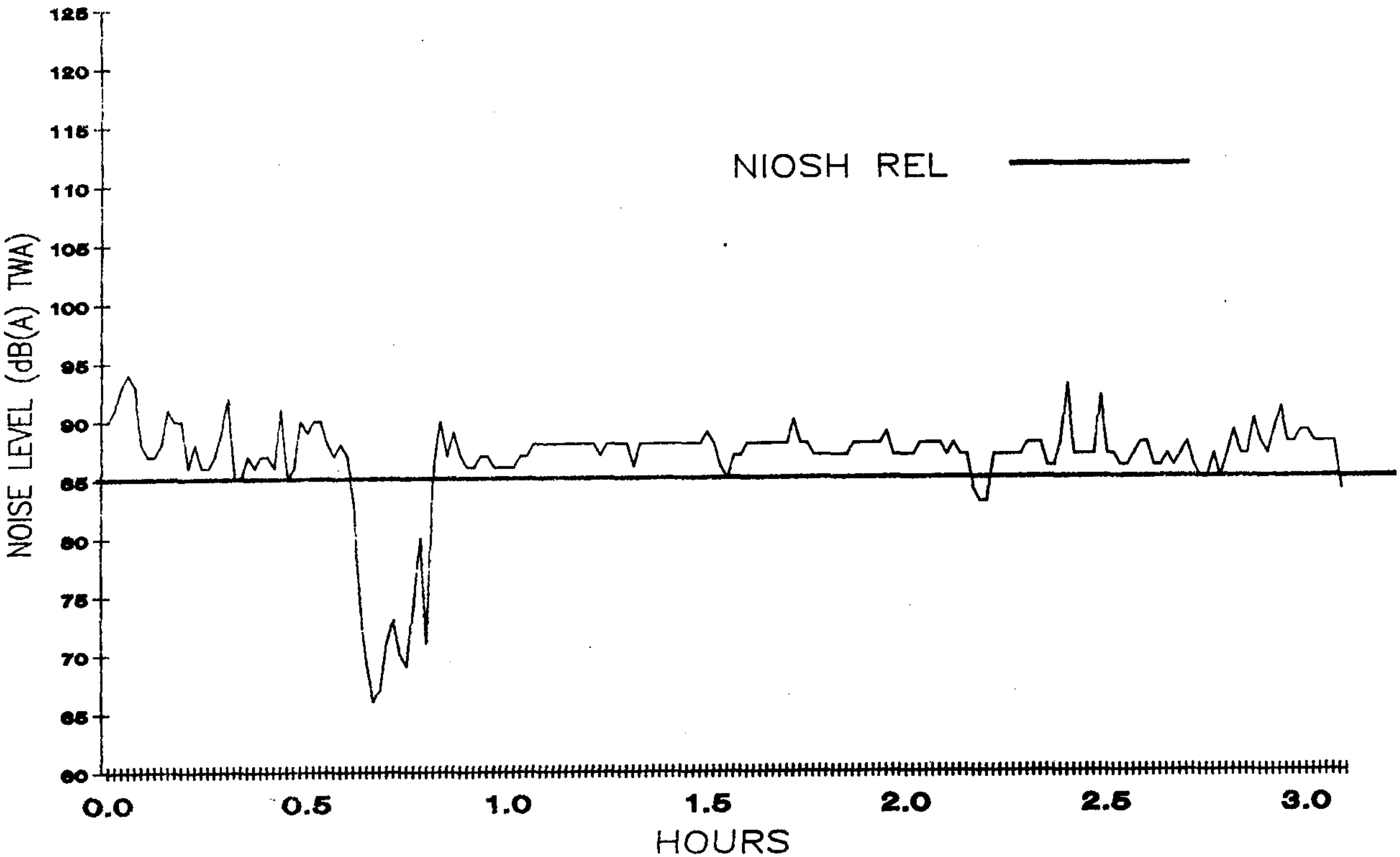


HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Packaging Machine Filler

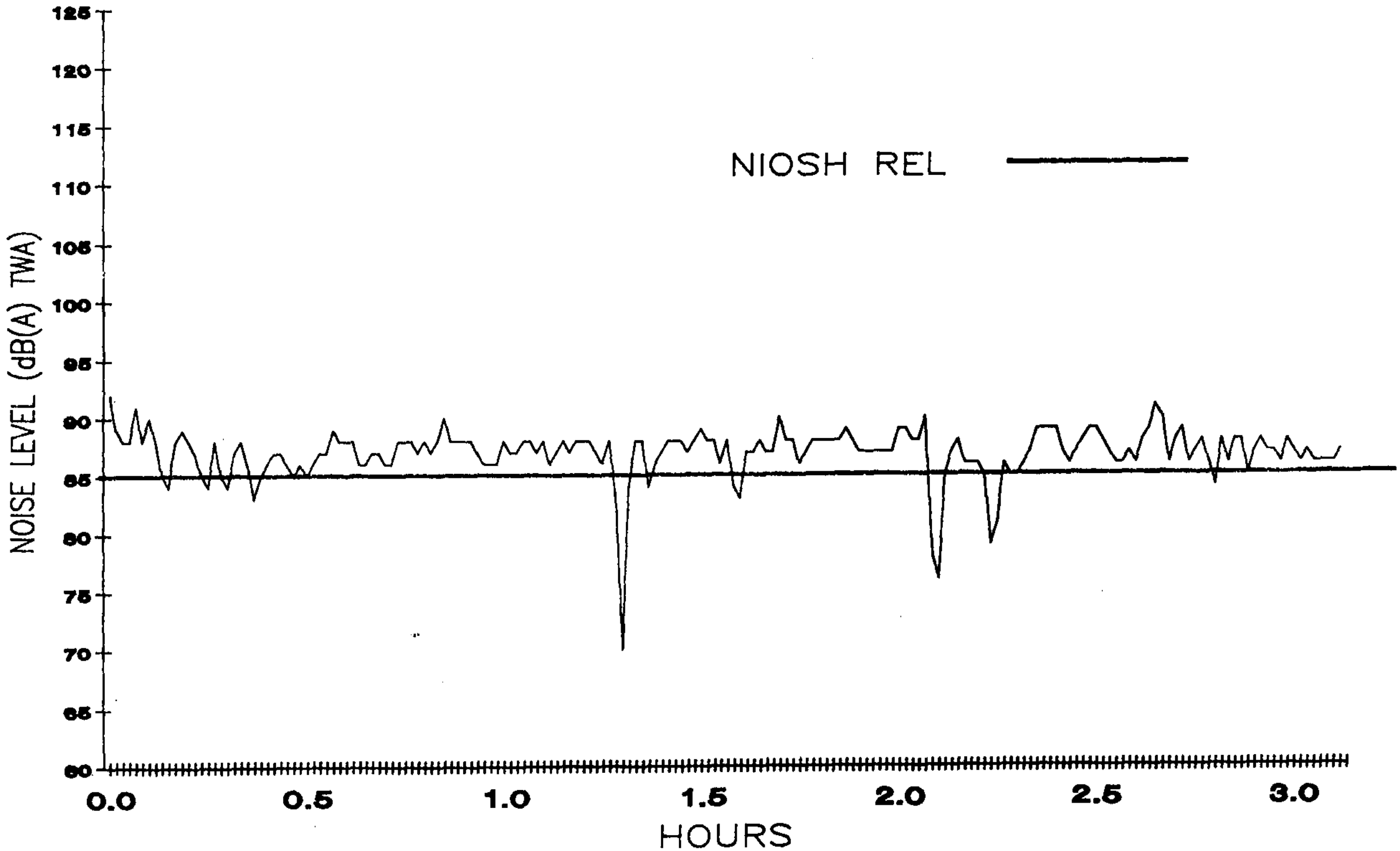


HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Packaging Machine Operator

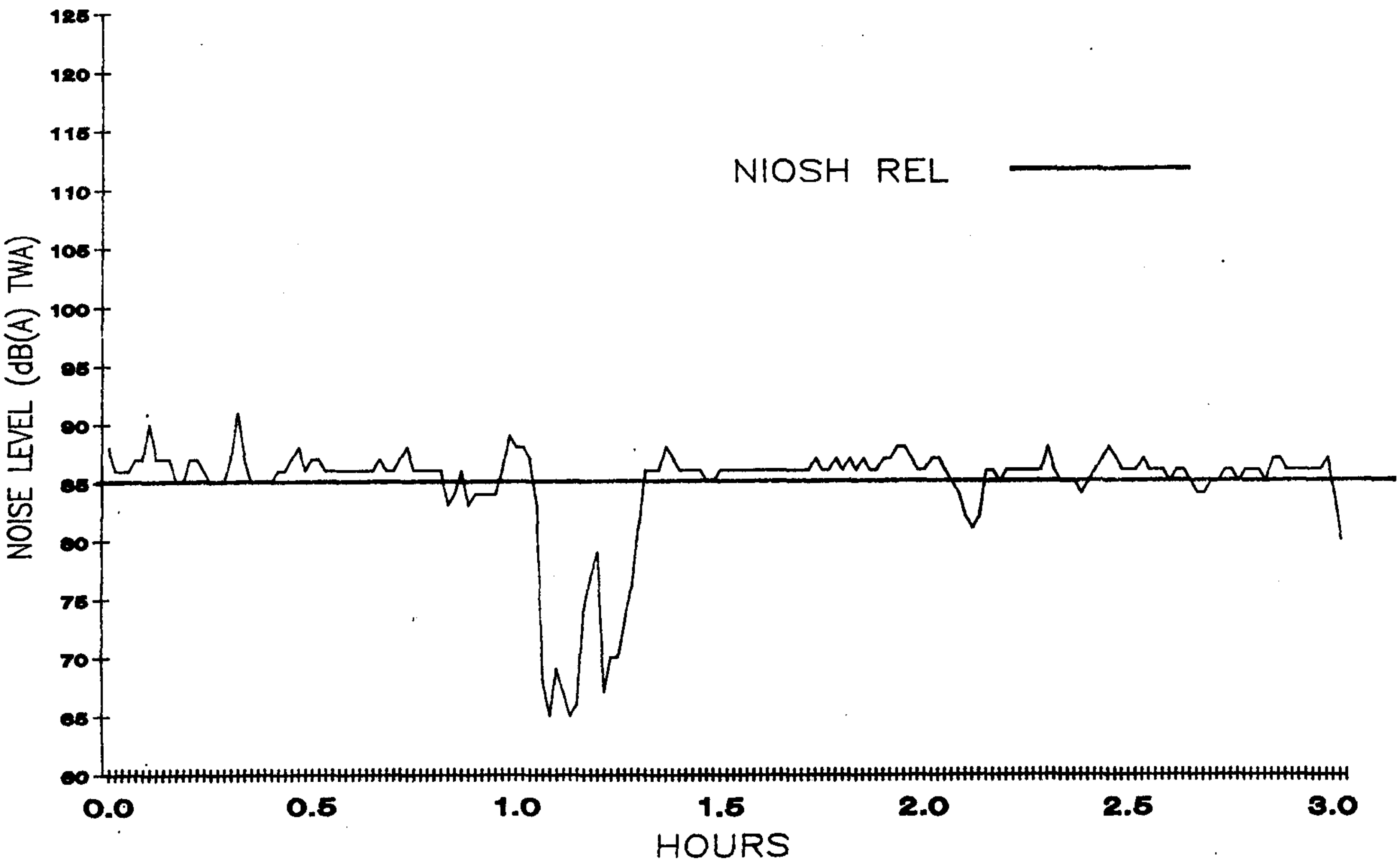


HETA 87-413

St. Lucia Noise Survey

N.Y. Daher Tobacco Co.

Cigarette Carton Packer

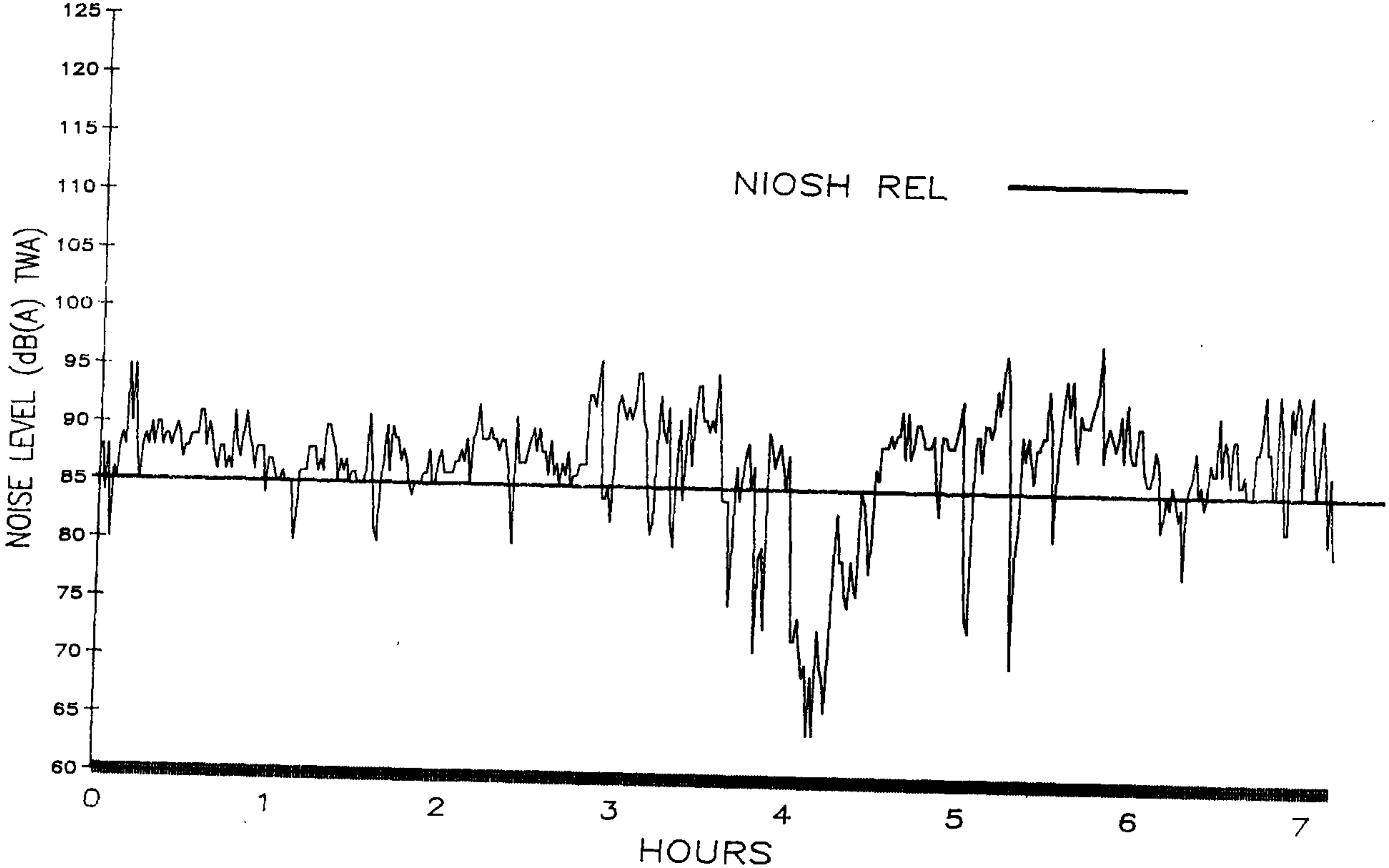


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Plastic Film Machine Operator "A"

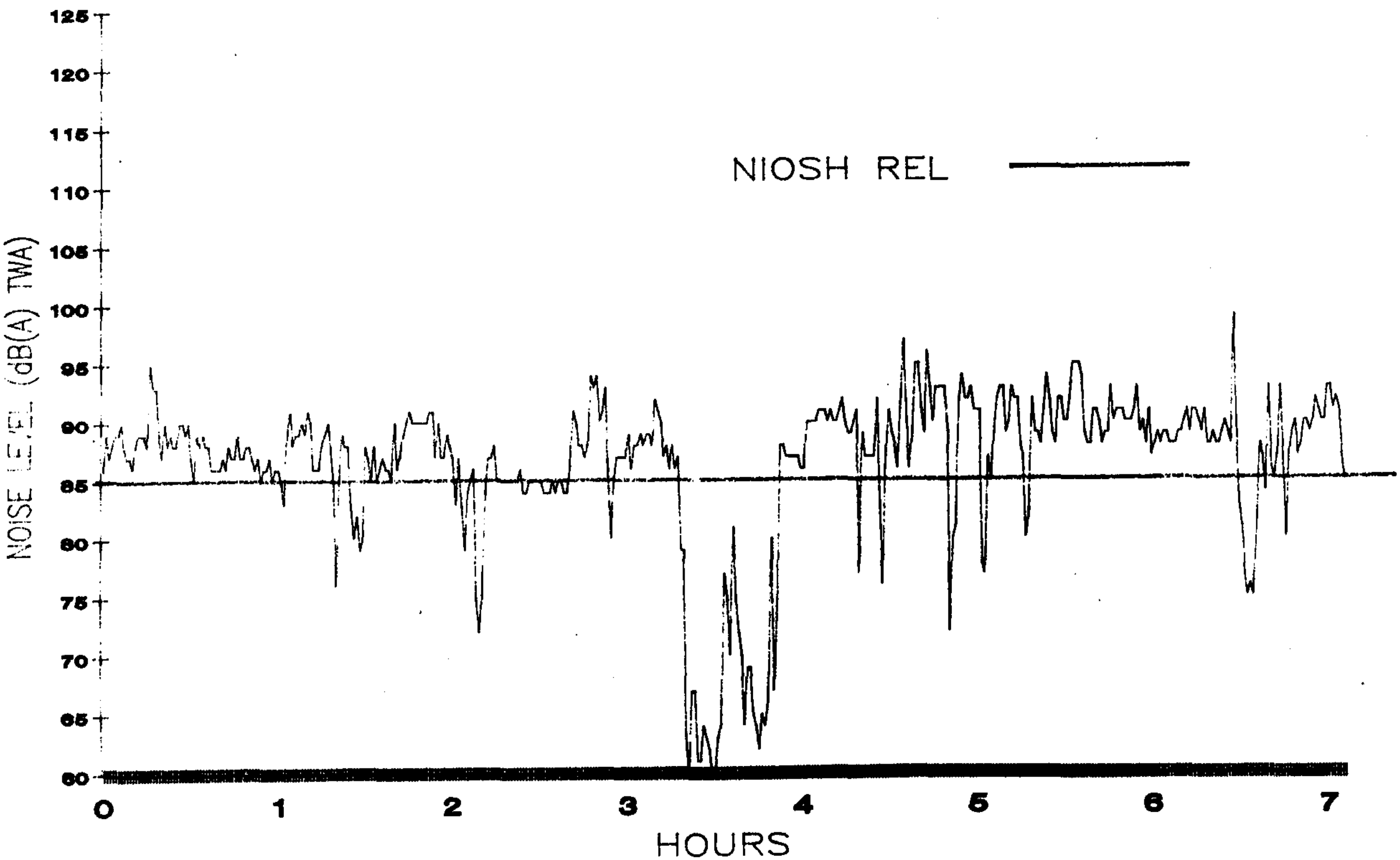


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Plastic Film Machine Operator "B"

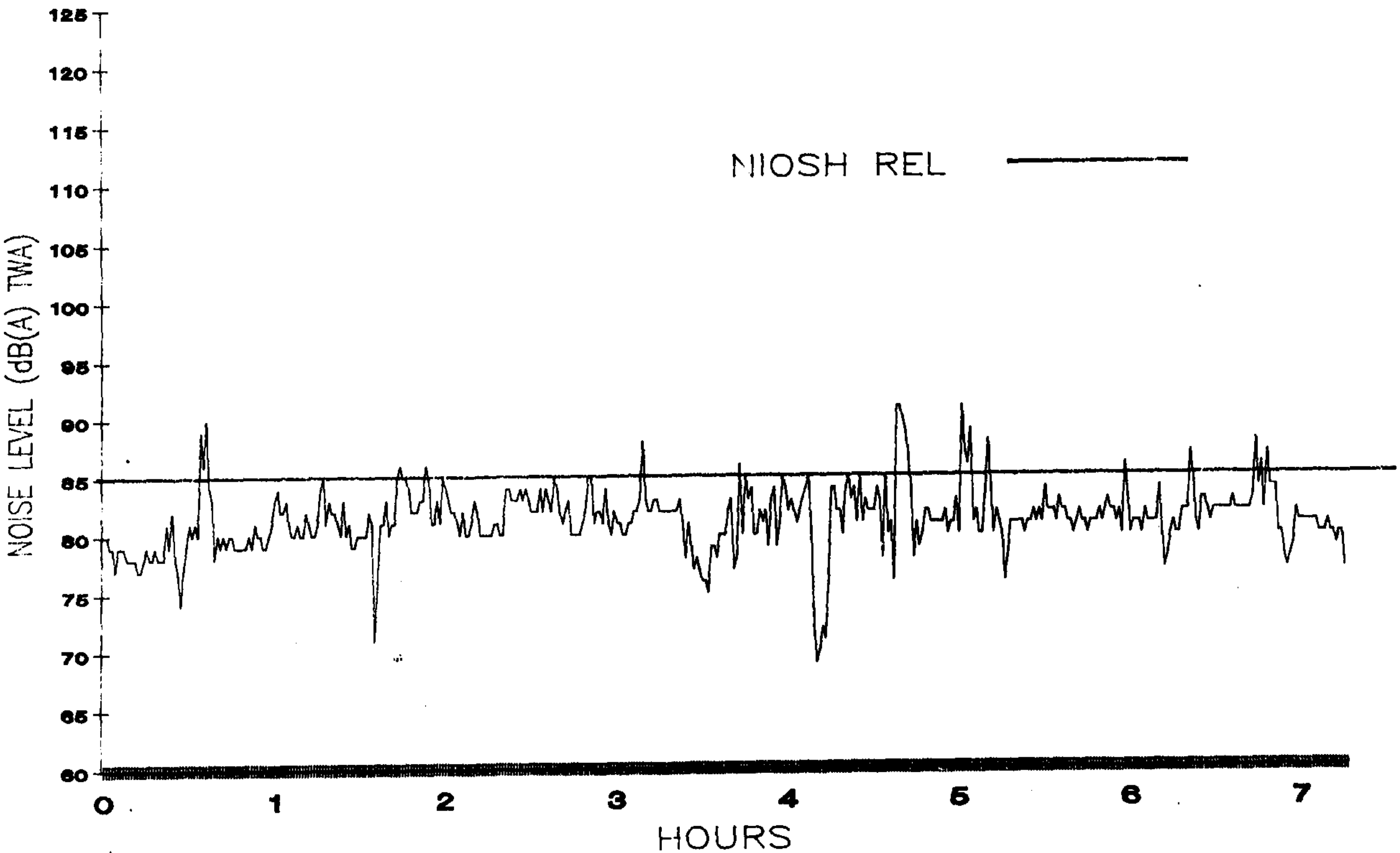


HETA 87-413

St. Lucia Noise Survey

Ramco Plastics

Bag Manufacturing Machine Operator "A"

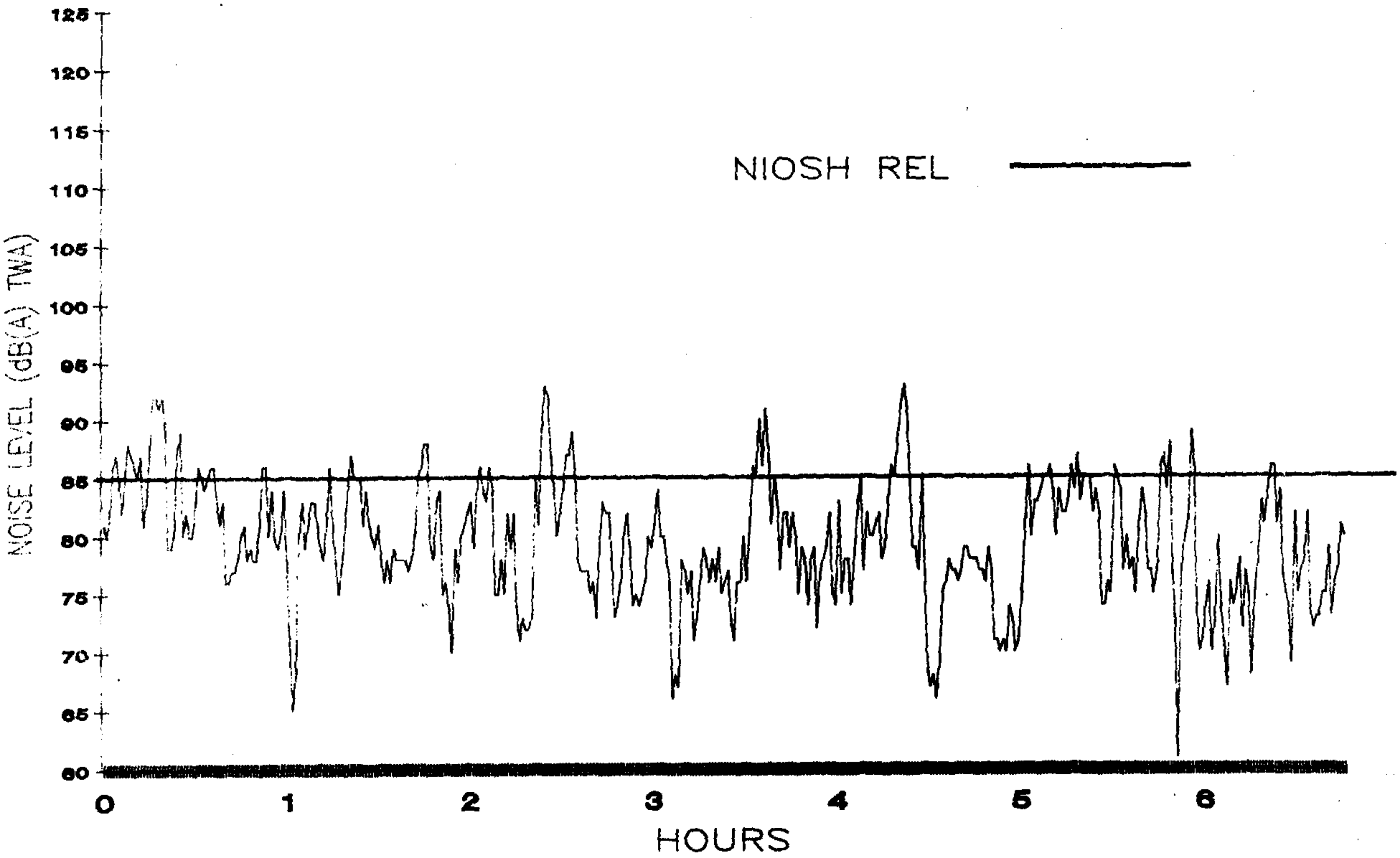


HETA 87-413

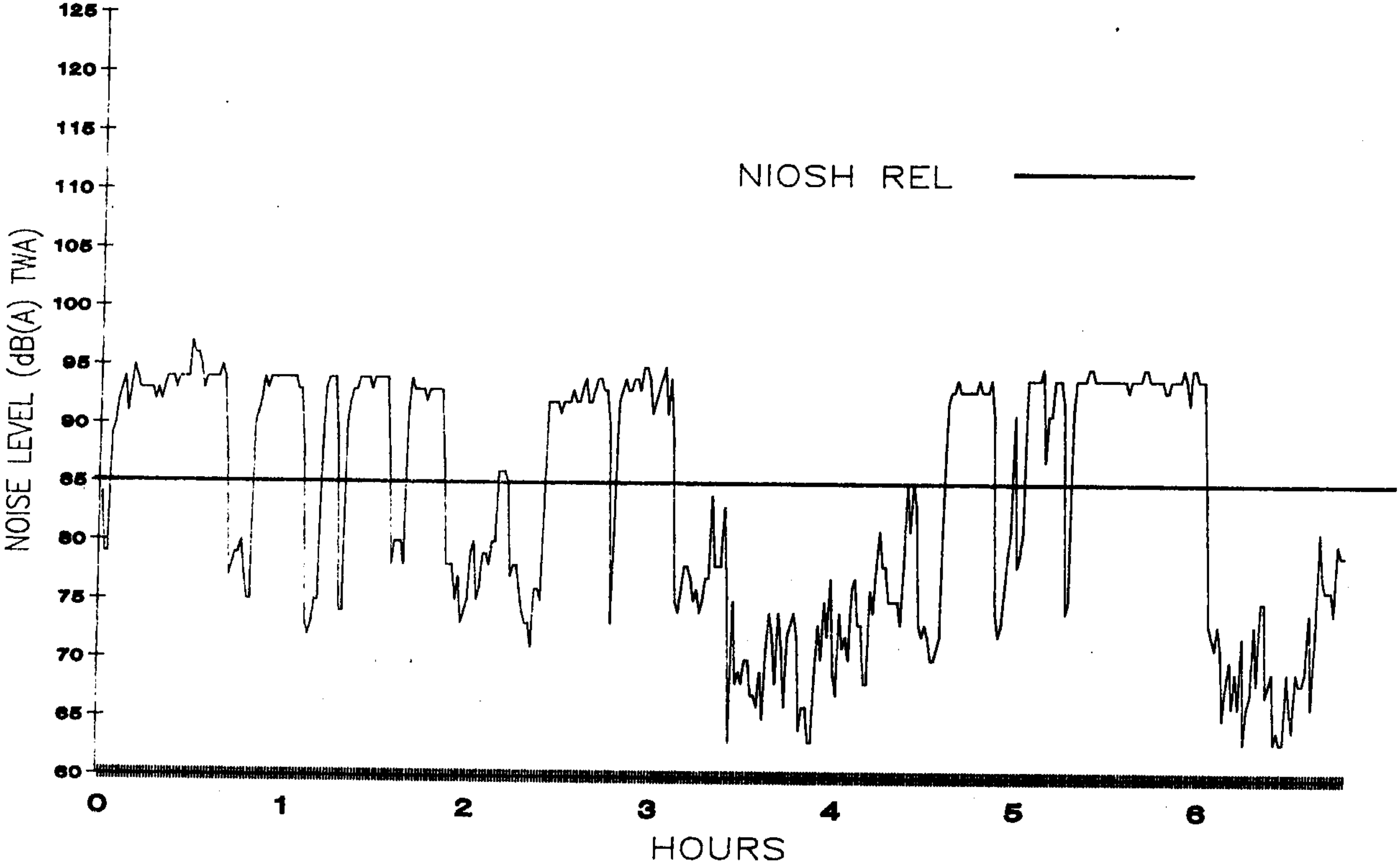
St. Lucia Noise Survey

Government Printery

Large Heidelberg Cylinder Printing Press Operator



HETA 87-413
St. Lucia Noise Survey
Government Printery
Monotype Caster

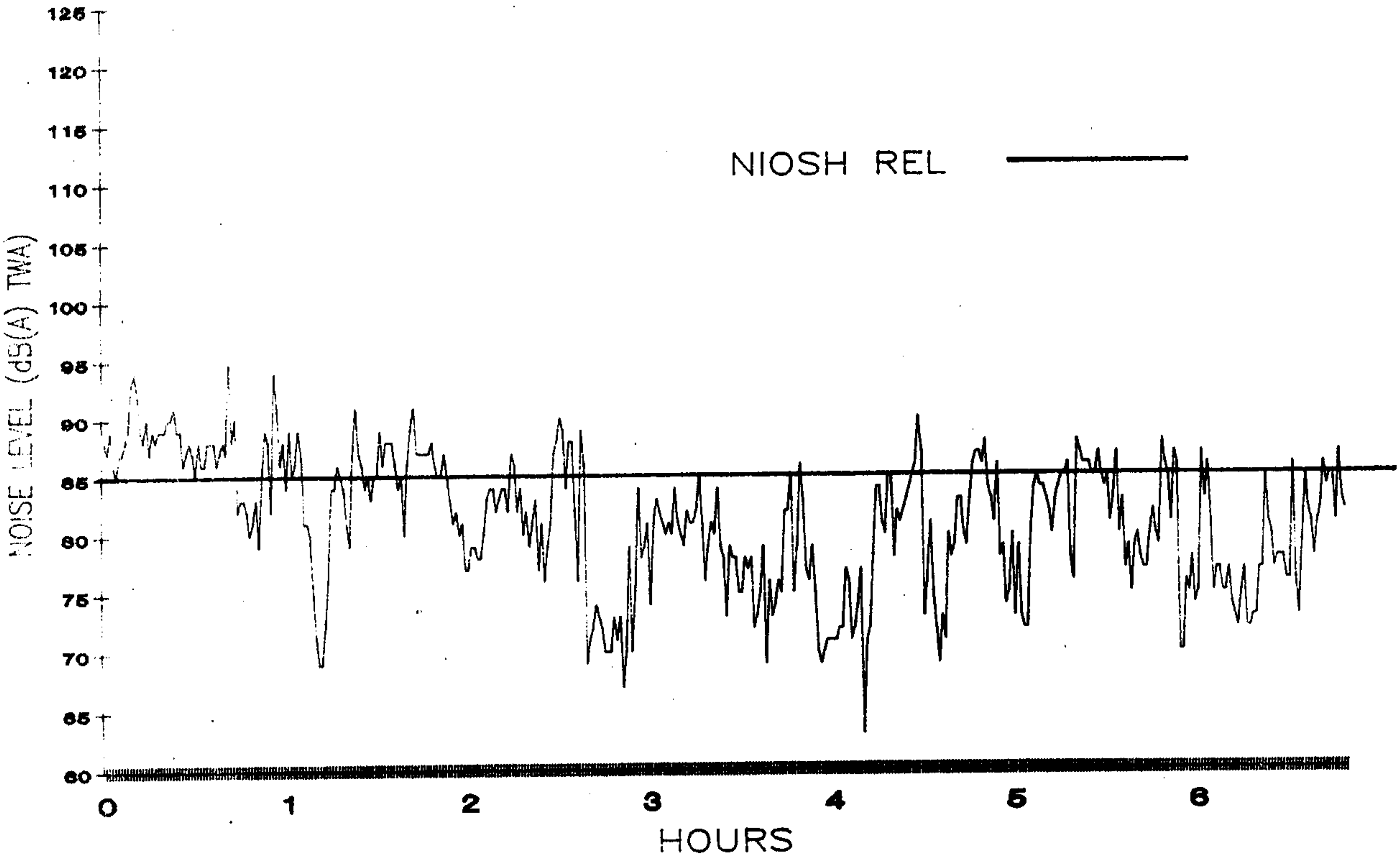


HETA 87-413

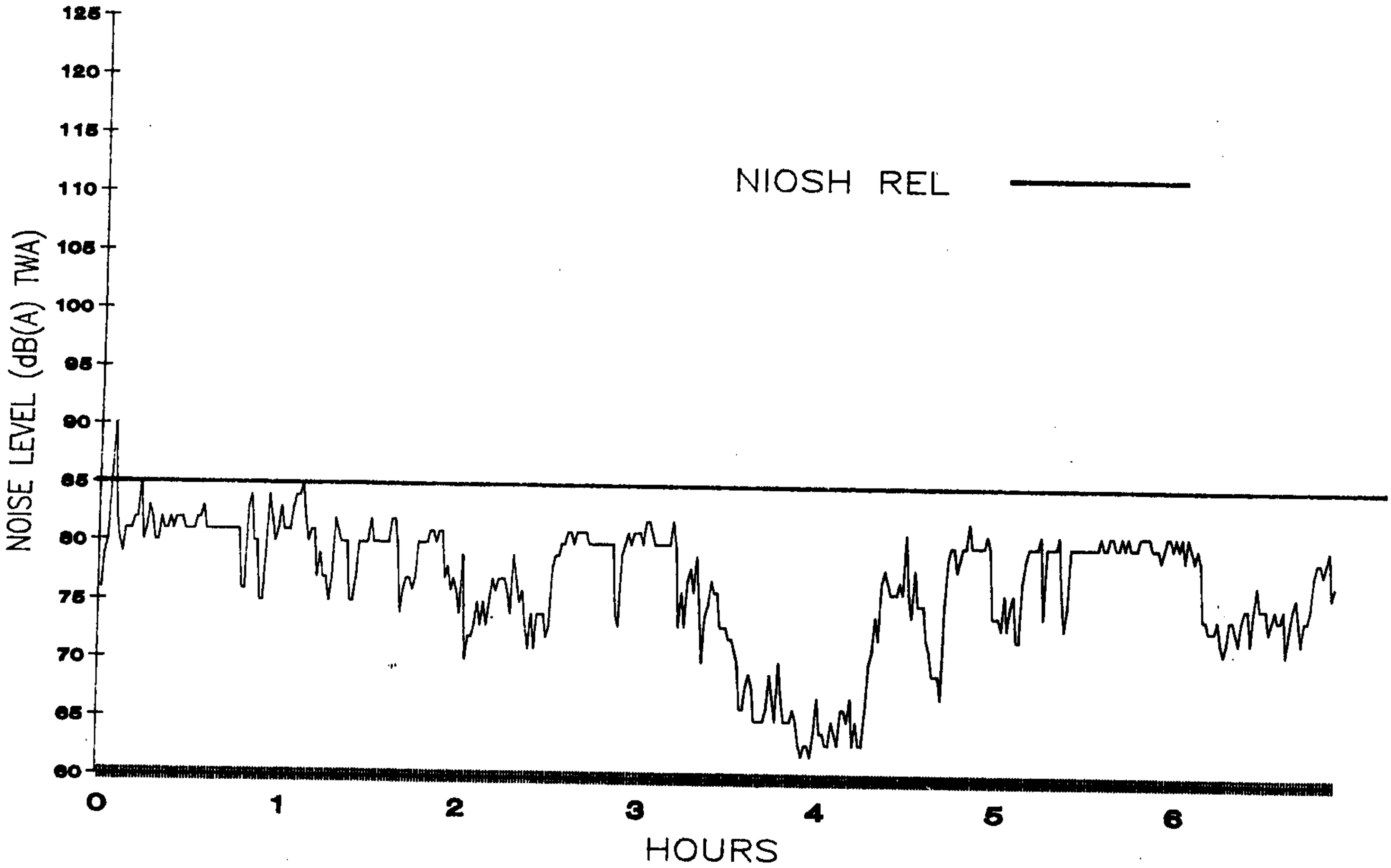
St. Lucia Noise Survey

Government Printery

Small Heidelberg Cylinder Printing Press Operator



HETA 87-413
St. Lucia Noise Survey
Government Printery
Linotype Operator



APPENDIX B

"Compendium of Hearing Protection Devices"

Compendium of Hearing Protection Devices

Barry L. Lempert
National Institute for
Occupational Safety and Health
Cincinnati, Ohio

Reprinted from SOUND AND VIBRATiON Magazine
May 1984, Vol. 18. No. 5

Compendium of Hearing Protection Devices

Barry L. Lempert, National Institute for Occupational Safety and Health, Cincinnati, Ohio

Data supplied to NIOSH by manufacturers or distributors of hearing protection devices are presented. These data include: supplier, model, type, weight, headband force, average attenuation values and standard deviations at test frequencies 125 to 8000 Hz, test standard, and test laboratory. Also presented are methods for calculating noise reduction factors for hearing protectors and a discussion of factors to be considered in the selection and use of these devices.

A list of hearing protector data and methods for computing noise reduction was published in September 1975 by the National Institute for Occupational Safety and Health (NIOSH)[1] in response to requests for information regarding the types of hearing protectors available for use in hearing conservation programs. Since that time, a modification (ANSI S3.19-1974)[2] of the standard laboratory method (ANSI Z24.22-1957)[3] for testing hearing protection devices has resulted in the retesting of most products. Also, some companies have left the market, and several new companies have asked that their products be incorporated. For these reasons, a new list has been compiled and is presented in this report.

Data supplied to NIOSH by manufacturers or distributors of hearing protection devices for inclusion in this report are presented in Appendix 1 *as received from the suppliers*. Included in Appendix 1 are: supplier, model, type, weight and headband force in ounces (oz.), average attenuation in decibels (dB) for the test frequencies from 125 to 8000 Hertz (Hz), and standard deviations in dB of these attenuation data. With few exceptions, the hearing protectors listed were tested by Paul L. Michael and Associates, Inc., State College, PA, using the new standard method. In those cases where a different test method or a different laboratory was used, the information is given in the footnotes referenced in the ID number column of Appendix 1.

In the earlier NIOSH report,[1] the majority of suppliers had their hearing protectors tested according to the American National Standards Institute (ANSI) standard Z24.22-1957, "Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold."[3] Almost all products reported herein have been tested in accordance with the new standard, ASA STD 1 1975 (ANSI S3.19-1974), "Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs."[2] The main differences between the ASA 1975 standard and the old standard are that the new standard requires use of third-octave bands of noise instead of discrete tones as the test stimuli and it requires a reverberant test room instead of an anechoic test room. Rigorous comparison of attenuation data obtained re Z24.22 presented in the previous (1975) report[1] with that obtained re S3.19-1974 presented in this report, has not been made. However, in general it appears that data obtained using the new standard show lower mean attenuation values as well as lower standard deviations. Also, attenuation data are presented in this report for "nonlinear" hearing protection devices, whereas such data were not available for inclusion in the previous (1975) report.[1] While standard methods for the real-ear evaluation of nonlinear devices, amplitude sensitive devices, and other hearing protection devices with features designed to operate exclusively against impulse noise are not yet established,[2] there is insufficient data to determine the existence of nonlinearity in continuous noise.

The results from tests using the procedures specified in the above mentioned standards are expressed in terms of the means and standard deviations of the attenuation in dB for each test frequency. These data can be used to make calculations of the noise reduction capabilities of the hearing protectors.

Three methods of making such calculations are presented in this report, along with examples. The attenuation values presented in Appendix 1 were measured under "experimenter (best) fit"[2] conditions in the laboratory. Even under these conditions, there is variation in attenuation from person to person and from test to test. In order to account for this variability, standard deviations can be included in the noise reduction calculations, as has been done in the examples. For each method, the limitations, advantages, and disadvantages are discussed. Except for two changes, these noise reduction computation methods are identical to those presented in the 1975 NIOSH report.[1] The two changes are: 1. the A-weighting* values for octave band sound levels have been reduced by 0.1 dB at 125, 250, and 500 Hz to conform with the weighting values in ANSI S1.4-1971 (R1976) "Specification for Sound Level Meters,"[4] and 2. the C-weighted** value for "pink" noise, or noise that has equal sound pressure levels at all octave bands, used in the second method has been reduced by 0.6 dB (see footnotes on page 29). With these two changes, the noise reduction constant designated R in the previous NIOSH report[1] has been converted to the Environmental Protection Agency's Noise Reduction Rating (NRR)[illegible] to minimize possible confusion.

Considerations in Selection and Use of Hearing Protectors

Calculated noise reduction factors as discussed herein are based on experimenter (best) fit data. To investigate the attenuation achieved in actual use, a field test method was developed by NIOSH and research studies were conducted, using this method.[illegible] The results of these *in-situ* attenuation tests of workers using preformed, acoustic wool, custom-molded, and acoustic foam earplugs, when compared to manufacturer's best-fit laboratory test results, indicated that 50% of the workers tested were receiving less than half the potential attenuation in dBA of the earplugs (determined using experimenter (best) fit mean attenuation values). Approximately 10% of the workers tested received less than 3 dB of protection, regardless of the type of earplug used.

In the area of muff-type protectors, the Mine Safety and Health Administration conducted a study where the noise was recorded simultaneously through microphones placed inside and outside the protective cup as the worker performed his normal work tasks.[7] The results, when compared to manufacturers' best-fit laboratory test results, were similar to those of the NIOSH studies.

Mention of commercial names, products, service or data herein, does not represent endorsement by NIOSH.

* A-weighting is a method of adjusting the noise levels to the response of the human ear.

** C-weighting gives essentially equal weight to the noise levels that can be heard by the human ear.

In order to appropriately estimate the actual noise reduction that will be achieved in actual use, there are several options. Some type of "user-informed fit" could be employed in the standard laboratory method; however, at present there is no concensus as to how to achieve consistency using such a procedure. Field data as those mentioned herein could be used to calculate noise reduction factors; however, substantially more data would need to be collected *and*, if two standard deviations were subtracted from the mean attenuation values in order to estimate the minimum noise reduction that would be achieved by 98% of the population, then the amount of noise reduction would be zero dB in most cases. Lastly, "derating" factors could be used in conjunction with the noise reduction factors presented in Methods 1, 2, and 3; however, more work must be done to arrive at a consistent and meaningful scheme for determining such factors.

Thus, in selecting a hearing protector, calculated noise reduction factors are one important consideration. However, other aspects must be considered which can affect the actual reduction achieved and the acceptance of the device by a worker. The possibility of wearer adjustment should be evaluated in terms of reliability of performance. Additional considerations are durability (shelf life or use life), sanitation-hygienic characteristics, the need of the worker to communicate verbally and to hear warning signals, environmental conditions such as heat, the time needed to install the device, and the amount of time(s) during the day that the device will be worn. If muff type hearing protection devices are used in a position other than "over-the-head" and a retaining strap is available, then it is important to utilize this option which should improve the reliability of the performance of the device. If custom-molded hearing protectors are to be used, the expertise of those persons who will prepare the impression materials and form the final mold should be considered.[5]

In use, factors which usually degrade the noise reduction are: improper fitting at the time of distribution, interference by hair or eyeglasses, and improper wearing by the worker. *Optimum fit of a hearing protector is most important in realizing the expected attenuation because it is on this basis that the attenuation data presented in Appendix 1 were derived.* Less than optimum fit is often a result of attempts to improve comfort and reduce the time needed to install the device. Many companies have found that the practices of personally fitting each worker, offering a variety to types to the workers, and providing regular and frequent monitoring of the proper use and fit of the protectors, have greatly improved acceptance of wearing hearing protectors.

Determination of Noise Reduction for Hearing Protectors

The attenuation data listed in this report show how the effectiveness of each hearing protector depends upon the frequency (Hz) × sound exposure level (dB) content of the assaulting noise. In industrial situations one usually needs to determine the amount by which the total workplace noise, usually expressed in sound levels on an A-scale, is effectively reduced by the hearing protector. Since industrial noise is usually made up of a mixture of individual sounds of various frequencies and strengths, termed its "spectrum," it is necessary to employ some sort of formula in computing the noise reduction to take account of its spectrum. If information regarding the workplace noise spectrum (typically expressed in octave band noise levels) is not available, then safety factors must be included to adjust for this spectral uncertainty. The performance of a hearing protector cannot be predicted exactly because of person to person and test to test variations, and it is appropriate to adjust for these measurement uncertainties as well. The purpose of this section is to provide the reader with the information needed to estimate the effective noise exposure level that may be achieved in a workplace when a hearing protector is worn in *optimum* fashion.

Through a series of calculations a dBA-reduction factor, R, is determined. After R has been calculated, it can be subtracted from the measured workplace dBA noise level to predict the effective noise exposure level of the worker. For example, if the measured workplace noise is 102 dBA and the R factor is 17 decibels, then the worker's effective noise exposure level should be no higher than 85 dBA. However, actual field performance may be substantially poorer than the expected performance if the protector is ill-fitted (see **Considerations in Selection and Use of Hearing Protectors**).

Three methods for calculating reduction factors will be presented with examples to illustrate how they are used. For all three methods, the calculations are similar, using logarithms and antilogarithms which many electronic calculators can compute with the "log x" button for logarithms and with the "10^x" or "y^x" button for antilogarithms. In general, the reduction factor equals the measured workplace noise level minus the effective noise level when wearing the hearing protector. The effective noise level is calculated differently in the three methods, depending upon the workplace noise data available. However, common to the three methods are: 1. the average attenuation at each octave band and a correction for uncertainty in measuring the attenuation; and 2. the dB A-weighting factor for each octave band. When taken together and subtracted from the octave band noise level in dB, these elements reduce the octave band noise level to the effective octave band noise level in dBA. In the equations to follow, these elements have been conveniently combined into a factor, Q, for each octave band.

A scheme for computing Q factors, using the data for the first hearing protector listed in Appendix 1 as an example, is presented in Table 1. Note that the average attenuation data for 3150 and 4000 Hz in Appendix 1 are averaged for computing Q factor 6, and similarly the data for 6300 and 8000 Hz have been averaged for computing Q factor 7. Twice the standard deviation has been used as the measurement uncertainty correction except for Q factors 6 and 7 where the standard deviations associated with the two frequencies involved have been added. The Q factors so calculated are listed in line 1 of Appendix 2, where the Q factors for all the hearing protectors listed in Appendix 1 are presented.

The three methods of calculating noise reduction factors differ in the type of noise data used and the resulting accuracy of the estimate. For Method 1, the most accurate method, octave band noise levels, the dBA noise level (which can be computed using the octave band levels), and the Q factors are required. For Method 2, the next most accurate method, octave band noise levels are not needed; what is needed is the difference between the dBC and dBA noise levels and the Q factors. For Method 3, only Q factors are needed. Method 2 yields a NRR for each hearing protector. The NRR, calculated as shown in the example for Method 2 for each hearing protector, is listed in Appendix 2 along with the Q factors for each hearing protector. It is required under 40 CFR 211.201 that each hearing protector be labeled with a NRR, however, the values listed in Appendix 2 may be different from those used by the manufacturer for a number of reasons: 1. an approximate tabular method for combining the effective (or "protected ear") octave band noise levels may be used instead of the more exacting method of using logarithmic calculations as shown in Method

Table 1. Scheme for calculating Q factors.

Factor Number	Octave Band Center Frequency (Hz)	Average Attenuation (dB) A	A-weighting Factor (dB) B	Measurement Uncertainty (dB) C	Q Factor (dB) A−B−C
1	125	21	16.1	2(2.4)	32.3
2	250	22	8.6	2(2.0)	26.6
3	500	24	3.2	2(2.1)	23.0
4	1000	30	0	2(2.4)	25.2
5	2000	36	1.2	2(2.5)	29.8
6	4000	(41 + 39)/2	1.0	[illegible] + 1.8	[illegible]
7	8000	(37 + 35)/2	1.1	2.5 + 2.7	[illegible]

2; 2. mean attenuation values for each product shown in this report are rounded to the nearest integer (values of 0.5 have been rounded down) and these rounded values were used to compute the NRR value shown in Appendix 2; 3. the manufacturer may label the protector at values different than indicated by the test results and by the computation procedure presented in this report; and 4. changes in the manufacturer's product and variability between different laboratory tests of the product.

The three computational methods usually yield different R factors for a given hearing protector/noise combination. The less precise methods are principally based on assumptions concerning *possible* noise spectra encountered in industry. These less precise methods include adjustments to guard against overestimating the R factor or underestimating the expected noise exposure when the hearing protector is used. As a general rule: the greater the accuracy of a method, the greater the computed value of R. Another consideration which affects the value of R in all methods is the adjustment factor to account for statistical variations from person to person. The adjustment procedure which has been used throughout this report is to reduce the listed attenuation values by subtracting twice the standard deviation values (or the equivalent when combining data; see Table 1) obtained in the laboratory measurements. This procedure should assure that most wearers will obtain the expected benefits from the hearing protector most of the time, when it is worn under the test conditions of optimum fit. If the standard deviations for a particular hearing protector are not available, then it may be suitable to use the worst-case data listed in Appendix 1 for other protectors of similar design. Alternatively, the reader may choose some adjustment for measurement uncertainty other than twice the listed standard deviation. (See **Considerations in Selection and Use of Hearing Protectors.**)

A guide for choosing a method for calculating noise reduction factors is presented in Table 2, and the detailed presentations and discussion of each method follow.

Table 2. Guide to choosing a method for computing noise reduction.

Method 1 (Most Accurate Method; Recommended)		
	Data required	Octave band noise levels at 125, 250, 500, 1000, 2000, 4000 and 8000 Hz, denoted by L_1, L_2, L_3, L_4, L_5, L_6, and L_7, respectively. The dBA noise level (which can be computed using the octave band noise levels). Q factors.
	Comments	Most precise of the three methods. Does not require an adjustment for spectral uncertainty. Computed R factor is appropriate only for a given noise spectrum, but the same R can be used for different dBA levels if only the intensity of the given noise changes. R factor is subtracted from the workplace dBA level to give the effective dBA level when the hearing protector is worn.
Method 2		
	Data required	The difference (δ) between the dBC and dBA levels is needed to compute R, but not for the modified R described below. δ (delta) = $L_C - L_A$. Q factors.
	Comments	Second-most precise of the three methods. Incorporates an adjustment of minus 3 dB to account for spectral uncertainty. The effective dBA level can be computed by using R or a modified R factor called "NRR." NRR is subtracted from the workplace dBC level, whereas R is subtracted from the dBA level. NRR is a constant, however R will change for each situation in which the δ is not the same.
Method 3 (Least Accurate)		
	Data required	Q factors.
	Comments	Least precise of the three methods. Incorporates an adjustment of minus 8.5 dB to account for spectral uncertainty (A less constraining procedure may be used if a certain assumption can be made—see "Discussion" for Method 3). R factor can be computed without noise level data. R factor is subtracted from workplace dBA level to give the effective dBA level.

Method 1: Detailed Presentation and Discussion

Formula

$$R = L_A - 10 \log S$$

where R = dBA-reduction factor

L_A = workplace dBA noise level

S = antilog $[(0.1)(L_1 - Q_1)]$ + antilog $[(0.1)(L_2 - Q_2)]$ + antilog $[(0.1)(L_3 - Q_3)]$ + antilog $[(0.1)(L_4 - Q_4)]$ + antilog $[(0.1)(L_5 - Q_5)]$ + antilog $[(0.1)(L_6 - Q_6)]$ + antilog $[(0.1)(L_7 - Q_7)]$

L_1, L_2, L_3, L_4, L_5, L_6, and L_7, denote octave band sound levels at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz, respectively

Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7, account for the attenuation of a given hearing protector (method for computation shown in Table 1)

Q factors for hearing protectors in Appendix 1 are in Appendix 2.

antilog $(x) = 10^x$

Example

Suppose a hearing protector is needed in an area with a noise level of 95 dBA and octave band noise levels of:

125	250	500	1000	2000	4000	8000 Hz
88	89	85	89	89	89	80 dB

and a fictitious hearing protector with the following mean attenuation and (standard deviation) characteristics is used:

125	250	500	1000	2000	3150	4000	6300	8000 Hz
21	22	23	29	41	47	43	40	37 dB
(3.7)	(3.3)	(3.8)	(4.7)	(3.3)	(4.0)	(2.7)	(6.0)	(6.6) dB

The "Q" (see Table 1 and Appendix 2) and "$L - Q$" values in S are:

$Q_1 = 21 + 16.1 - (2)(3.7) = 29.7 \quad (L_1 - Q_1) = 88 - 29.7 = 58.3$

$Q_2 = 22 + 8.6 - (2)(3.3) = 24.0 \quad (L_2 - Q_2) = 89 - 24.0 = 65.0$

$Q_3 = 23 + 3.2 - (2)(3.8) = 18.6 \quad (L_3 - Q_3) = 85 - 18.6 = 66.4$

$Q_4 = 29 + 0 - (2)(4.7) = 19.6 \quad (L_4 - Q_4) = 89 - 19.6 = 69.4$

$Q_5 = 41 - 1.2 - (2)(3.3) = 33.2 \quad (L_5 - Q_5) = 89 - 33.2 = 55.8$

$Q_6 = (47 + 43)/2 - 1.0 - 4.0 - 2.7 = 37.3$

$(L_6 - Q_6) = 89 - 37.3 = 51.7$

$Q_7 = (40 + 37)/2 + 1.1 - 6.0 - 6.6 = 27.0$

$(L_7 - Q_7) = 80 - 27.0 = 53.0$

Applying the formula for the dBA reduction factor,

$$R = L_A - 10 \log S$$

where $L_A = 95$

and S = antilog $[(0.1)(58.3)]$ + antilog $[(0.1)(65.0)]$ + antilog $[(0.1)(66.4)]$ + antilog $[(0.1)(69.4)]$ + antilog $[(0.1)(55.8)]$ + antilog $[(0.1)(51.7)]$ + antilog $[(0.1)(53.0)]$

= 676,083 + 3,162,278 + 4,365,158 + 8,709,636 + 380,189 + 147,911 + 199,526

= 17,640,781

$$R = 95 - 10 \log (17,640,781) = 95 - 72.5 = \mathbf{22.5\ dB}$$

The effective dBA level is

$$L_A - R = 95 - 22.5 = 72.5 \text{ dBA},$$

which, incidentally, is equal to the value of the term "10 log S." Alternatively, the effective dBA level can be estimated using the "$L - Q$" values and Table 3, as shown in Table 4. Use of Table 3 to determine the effective dBA level can result in an overestimate of the R factor of 0.3 dB.

Discussion

The R factor calculated by this method only has an adjustment to account for measurement uncertainty which is accomplished by subtracting twice the standard deviation values from the corresponding attenuation values. No adjustment for spectral uncertainty is needed because the attenuation data are subtracted directly from the octave band levels of the noise. This is the most precise method and may be used as an ideal reference against which other methods can be compared.

This method has the drawback that a different R has to be calculated for each noise spectrum, but the same R can be used for different dBA levels if only the level of the given noise changes.

The use of this method is strongly recommended when speech communication or the ability to hear other environmental information is an important concern.

Method 2: Detailed Presentation and Discussion

Formula

$$R = \text{NRR} - \delta = (4.9 - 10 \log T) - \delta$$

where R = dBA-reduction factor

NRR = 4.9 − 10 log T (see Discussion)

$T = \text{antilog}\,[(-0.1)(Q_1)] + \text{antilog}\,[(-0.1)(Q_2)] + \text{antilog}\,[(-0.1)(Q_3)] + \text{antilog}\,[(-0.1)(Q_4)] + \text{antilog}\,[(-0.1)(Q_5)] + \text{antilog}\,[(-0.1)(Q_6)] + \text{antilog}\,[(-0.1)(Q_7)]$

$\delta = L_C - L_A$

L_C = workplace dBC noise level

L_A = workplace dBA noise level

Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7, account for the attenuation of a given hearing protector (method for computation shown in Table 1)

NRR values are given in Appendix 2 for hearing protectors in this list.

The expression antilog $[(-0.1)(Q)]$ is equivalent to antilog $[(0.1)(L - Q)]$, where $L = 0$.

antilog $(x) = 10^x$

Example

Suppose a fictitious hearing protector with the following mean attenuation and (standard deviation) characteristics is used:

125	250	500	1000	2000	3150	4000	6300	8000 Hz
21	22	23	29	41	47	43	40	37 dB
(3.7)	(3.3)	(3.8)	(4.7)	(3.3)	(4.0)	(2.7)	(6.0)	(6.6) dB

If this hearing protector were actually in the list, NRR could be found by using the protector's I.D. No. to locate the value in Appendix 2. In this case, however, the "10 log T" value must be computed as shown below and is equal to −14.9. Workplace noise levels are: L_C = 96, L_A = 95. Applying the formula,

$$R = \text{NRR} - \delta$$

where $\text{NRR} = 4.9 - 10 \log T = 4.9 - (-14.9) = 19.8$ dB

$\delta = 96 - 95 = 1$

$$R = 19.8 - 1 = \mathbf{18.8\ dB}$$

The effective dBA level is

$$L_A - R = 95 - 18.8 = 76.2 \text{ dBA}$$

or, using NRR and the dBC noise level, the effective dBA level is

$$L_C - \text{NRR} = 96 - 19.8 = 76.2 \text{ dBA}$$

Computation of 10 log T

The "Q" values in are:

$Q_1 = 21 + 16.1 - (2)(3.7) = 29.7$

$Q_2 = 22 + 8.6 - (2)(3.3) = 24.0$

$Q_3 = 23 + 3.2 - (2)(3.8) = 18.6$

$Q_4 = 29 + 0 - (2)(4.7) = 19.6$

$Q_5 = 41 - 1.2 - (2)(3.3) = 33.2$

$Q_6 = (47 + 43)/2 - 1.0 - 4.0 - 2.7 = 37.3$

$Q_7 = (40 + 37)/2 + 1.1 - 6.0 - 6.6 = 27.0$

and $T = \text{antilog}\,[(-0.1)(29.7)] + \text{antilog}\,[(-0.1)(24.0)] + \text{antilog}\,[(-0.1)(18.6)] + \text{antilog}\,[(-0.1)(19.6)] + \text{antilog}\,[(-0.1)(33.2)] + \text{antilog}\,[(-0.1)(37.3)] + \text{antilog}\,[(-0.1)(27.0)]$

$= 0.00107 + 0.00398 + 0.01380 + .01096 + 0.00048 + 0.00019 + 0.00200$

$= 0.03248$

$$10 \log T = 10 \log (0.03248) = (10)(-1.49) = -14.9$$

Discussion

This method is based upon a simplifying assumption which is applied to a procedure developed by J. Botsford.[10] A "sound level conversion" value, or a modified R factor (denoted herein as NRR), is computed by using the attenuation data of a hearing protector and a single noise spectrum which is composed of equal sound pressure levels for all octave bands ("pink" noise). [This noise spectrum represents the median "shape," with δ equal to approximately 1.5, of the sample of 100 noise spectra shown in Figure 1 of the previous (1975) report,[1] which were chosen to correspond to the distribution of noise exposures found in major industries in the U.S.] The computation of NRR involves subtracting the effective dBA level from the dBC level of the assumed pink noise. The result of this subtraction can be shown to equal "7.9 − 10 log T", where T is derived from the hearing protector attenuation data including adjustments for measurement uncertainty.* However, an additional adjustment** of 3 dB is then required to protect against overestima-

*The value 7.9 dB corresponds to the dBC level for pink noise used in the EPA Noise Reduction Rating (NRR) which was computed over the octave bands 125 to 8000 Hz. In the previous NIOSH (1975) report,[1] dBC levels were computed over the [illegible] to 8000 Hz octave bands (for all noise spectra used in the determination of correction factors for spectral uncertainty; see footnote below) and the pink noise value was 8.5 dB.

**This adjustment factor is the 98th percentile point in the error distribution of values of R computed using δ as an index of the noise spectrum versus values of R computed using octave band sound pressure levels. This factor was determined using the attenuation data and the 100 noise spectra presented in the previous (1975) report[1] and a pink noise dBC level of 8.5 dB. If the pink noise value of 7.9 dB had been included in the determination of the 98th percentile adjustment factor, then this factor would have been 2.4 dB instead of 3 dB. Thus, an additional adjustment factor of 0.6 dB has been included.

Table 3. Values used for summing two decibel (dB) levels.

Higher Minus Lower Level	Add to Higher Level	Higher Minus Lower Level	Add to Higher Level
0.0 to 0.1	3.0	3.7 to 4.0	1.5
0.2 to 0.3	2.9	4.1 to 4.3	1.4
0.4 to 0.5	2.8	4.4 to 4.7	1.3
0.6 to 0.7	2.7	4.8 to 5.1	1.2
0.8 to 0.9	2.6	5.2 to 5.6	1.1
1.0 to 1.2	2.5	5.7 to 6.1	1.0
1.3 to 1.4	2.4	6.2 to 6.6	0.9
1.5 to 1.6	2.3	6.7 to 7.2	0.8
1.7 to 1.9	2.2	7.3 to 7.9	0.7
2.0 to 2.1	2.1	8.0 to 8.6	0.6
2.2 to 2.4	2.0	8.7 to 9.6	0.5
2.5 to 2.7	1.9	9.7 to 10.7	0.4
2.8 to 3.0	1.8	10.8 to 12.2	0.3
3.1 to 3.3	1.7	12.3 to 14.5	0.2
3.4 to 3.6	1.6	14.6 to 19.3	0.1
		= or > 19.4	0.0

Table 4. Example for using Table 3 to sum seven octave band levels in Method 1 example (seven octave band levels shown are seven "L − Q" values).

Octave Band Level	Previous Result	Higher Minus Lower Level	Add to Higher Level		Higher Level		Result
58.3	-	-	-		-		58.3
65.0	58.3	6.7	0.8	+	65.0	=	65.8
66.4	65.8	0.6	2.7	+	66.4	=	69.1
69.4	69.1	0.3	2.9	+	69.4	=	72.3
55.8	72.3	16.5	0.1	+	72.3	=	72.4
51.7	72.4	20.7	0.0	+	72.4	=	72.4
53.0	72.4	19.4	0.0	+	72.4	=	72.4

tion because of the possible variations in the spectra of actual workplace noises. The dBA reduction factor, R, is then just NRR minus δ. Thus, the expression for R is:

$$R = 7.9 - 10 \log T - \delta - 3 = 4.9 - 10 \log T - \delta = \text{NRR} - \delta$$

As shown in the example for this method, the effective dBA level can be computed using NRR as well as R. The only difference is that NRR is subtracted from the dBC level whereas R is subtracted from the dBA level. Being a constant for a given hearing protector, NRR is convenient to use if the workplace dBC noise level is known; furthermore, it makes determination of δ unnecessary. R, however, is dependent on the value of δ (i.e. $L_C - L_A$) for the workplace noise and is not necessarily constant for a given hearing protector.

Since a variable R factor could cause some difficulty in its use, a conservative procedure can be used to calculate a constant value of R if one has sufficient knowledge of the δ values of noise in the workplace. The procedure is to determine the highest value of δ at the workers' positions of concern and use that value in the equation for R. The resulting R factor can be subtracted from dBA levels throughout the workplace to determine the effective dBA noise levels. As an example, if one were sure that the value of δ were no greater than 5.0 at all locations in his factory, then a single R factor of 14.8 dB could be used for the hearing protector of the above example ($R = \text{NRR} - \delta = 19.8 - 5.0$).

Method 3: Detailed Presentation and Discussion

Formula

$$R = -1.5 - 10 \log T \cong \text{NRR} - 7$$

where R = dBA reduction factor

NRR = $4.9 - 10 \log T$ (see discussion of NRR under Method 2)

$$T = \text{antilog}[(-0.1)(Q_1)] + \text{antilog}[(-0.1)(Q_2)] + \text{antilog}[(-0.1)(Q_3)] + \text{antilog}[(-0.1)(Q_4)] + \text{antilog}[(-0.1)(Q_5)] + \text{antilog}[(-0.1)(Q_6)] + \text{antilog}[(-0.1)(Q_7)]$$

$Q_1, Q_2, Q_3, Q_4, Q_5, Q_6$, and Q_7 account for the attenuation of a given hearing protector (method for computation shown in Table I)

antilog $(x) = 10^x$

Example

As an example, the fictitious hearing protector used under Method 2, with a "10 log T" value of −14.9, is used below. Applying the formula,

$$R = -1.5 - 10 \log T = -1.5 - (-14.9) = \mathbf{13.4\ dB}$$

For a workplace dBA level of 95, the effective dBA level is $L_A - R$ = 95 − 13.4 = 81.6 dBA

Discussion

This method requires no noise measurements to compute R. The formula has been derived by assuming a noise spectrum which is composed of equal sound pressure levels for all octave bands ("pink" noise). [This noise spectrum represents the median "shape" of the sample of 100 noise spectra shown in Figure 1 of the previous (1975) report, which were chosen to correspond to the distribution of noise exposures found in major industries in the U.S.] The computation of R involves subtracting the effective dBA level from the dBA level of the assumed pink noise. The result of this subtraction can be shown to equal "$7.0 - 10 \log T$", where T is derived from the hearing protector attenuation data including adjustments for measurement uncertainty. However, an additional adjustment* of 8.5 dB is then required to protect against overestimation of R because of variation in the noise spectra of actual industrial noises. The resulting expression for R is:

$$R = 7.0 - 10 \log T - 8.5 = -1.5 - 10 \log T$$

Once the value of "10 log T" is determined, R is computed by a single subtraction. A possible disadvantage with this method is that too low of a value of R might result because of the necessity for having a large adjustment factor (8.5 dB). To demonstrate differences that can occur between the methods, the R factors in the examples for Methods 1, 2, and 3 were computed using the same hearing protector and the same noise data. The results are: Method 1 (22.5 dB), Method 2 (18.8 dB), and Method 3 (13.4 dB). If an unsatisfactory R is computed using Method 3, several alternatives are available to the user. Possibly a different hearing protector with a larger R factor could be selected, or additional noise data (octave band sound levels or dBC levels) can be obtained in order to use Method 1 or Method 2, which will usually yield greater values of R. However, given the likelihood that the true noise reduction factor is typically at least 6 dB higher (possibly as much as 12 dB higher depending on the actual noise spectrum), use of dBC levels or octave band levels is strongly recommended when speech communication or other environmental information is an important concern.

Even if the noise data needed to compute R by Method 2 is not directly available, the Method may still be used if a certain assumption can be made about the term δ (delta), which is the difference between the dBC (L_C) and dBA (L_A) levels of the workplace noise ($\delta = L_C - L_A$). The procedure is to assume the highest value of δ expected for actual noises within a given workplace and use that value in the formula for R presented in Method 2 (i.e. $R = 4.9 - 10 \log T - \delta$). The assumed value of δ should be based on actual noise measurements, noise data from a similar operation, or some other well-founded reason.

The formula for R in Method 3 can be rearranged to illustrate how it is similar to the Method 2 formula:

$$R = -1.5 - 10 \log T = 4.9 - 10 \log T - 6.4 \cong \text{NRR} - 7$$

In this form, the Method 3 formula is shown to be equal to the Method 2 formula for a δ value of approximately 7.** This point is important because a certain amount of caution should be exercised in using Method 3 in workplaces where dBC − dBA ($L_C - L_A$) differences might be greater than 7. This situation is relatively easy to recognize because it implies dominant low frequency noise, with a substantial rumble or roar. This slight restriction in the application of the formula emerged out of the development of the method. Method 3 was designed to meet the requirement of: 1. having a simple, short procedure for calculating R without knowing any noise levels; 2. obtaining a constant R factor (for a given hearing protector) which can be subtracted from measured dBA levels to give the effective dBA level; and 3. having a value of R which is not unreasonably small for most protectors. Without the indicated restriction, an adjustment factor larger than 8.5 dB would be needed which could result in values of R being almost too low to be useful. Therefore, use caution in applying a Method 3 R factor if low frequency noises are present, and when in doubt, use Method 1 or 2, if possible.

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*This adjustment factor is the 98th percentile point in the error distribution of values of R computed by the Method 3 procedure versus values of R computed using octave band sound pressure levels. This factor was determined using the attenuation data and the 100 noise spectra presented in the previous (1975) report.

**Although the formula $R = \text{NRR} - 6.4$ is consistent with the correction factor of 8.5 dB for spectral uncertainty, the "approximate" formula $R \cong \text{NRR} - 7$ is presented to avoid undue confusion with applications of Method 3 as presented in the previous (1975) report.

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